APPENDIX C: INDIA'S QUANTUM POLICY AND REGULATION[1]

Table of Contents

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1. What has India done to date on Quantum strategy and policy?

India is the seventh country to launch a quantum program.[2] The country's first quantum computing-based telecom network link was launched in March 2023.[3] Presently, India has nearly a hundred quantum projects, of which about 92 percent are sponsored by the Centre.[4]

The execution of India's quantum strategy is meted out by different **governing bodies**:

- The Ministry of Science and Technology (MoS&T),[5] Department of Science and Technology (DST)[6] and Centre for Development of Telematics (C-DOT).[7] DST is at the forefront of R&D initiatives under India's quantum strategy.
- The Ministry of Electronics and Information Technology (MEITY)[8] is also a major stakeholder in R&D initiatives, through its divisions like the Centre for Development of Advanced Computing (C-DAC).[9]
- In 2020, the Ministry of External Affairs (MEA)[10] established a new department -- New, Emerging and Strategic Technologies (NEST), to engage in technology diplomacy and deal with the foreign policy and international legal aspects of new and emerging technologies.
- The Prime Minister's Science, Technology and Innovation Advisory Council (PM-STIAC)[11] assesses the status in specific science and technology domains, comprehends challenges, formulates interventions, develops a futuristic roadmap, and advises the PM accordingly.
- Department of Space/Indian Space Research Organisation (DoS/ISRO)[12]
- Department of Atomic Energy (DAE)[13]
- Defence Research and Development Organisation (DRDO)[14]

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[2] Kalyan Ray, 'India to Become Seventh Nation to Have National Quantum Mission', *Deccan Herald* (online, 20 April 2023) <https://www.deccanherald.com/india/india-to-become-seventh-nation-to-have-national-quantum-mission-1211108.html>.
[3] Press Trust of India, 'India's First Quantum Computing-Based Telecom Network Link Now Operational: Ashwini Vaishnaw', *The Economic Times* (online, 27 March 2023) <https://economictimes.indiatimes.com/industry/telecom/telecom-news/indias-first-quantum-computing-based-telecom-network-link-now-operational-ashwini-vaishnaw/articleshow/99026697.cms?from=mdr>.
[4] Press Information Bureau, *Industry Will Be Expected to Be a Major Resource Contributor in All the Future StartUp Ventures and Other New Technology Initiatives, Says Union Minister Dr Jitendra Singh* (Press Release, 5 October 2023) <https://pib.gov.in/PressReleseDetailm.aspx?PRID=1964650>.
[5] 'About Ministry of Science & Technology, Government of India', *Ministry of Science & Technology, Government of India* (Web Page) <https://most.gov.in/about-us.html>.
[6] 'Department Of Science & Technology | विज्ञान एवं प्रौद्योगिकी विभाग', *Government of India, Ministry of Science and Technology* (Web Page) <https://dst.gov.in/>.
[7] *Centre for Development of Telematics* (Web Page) <https://www.cdot.in/cdotweb/web/home.php>.
[8] *Ministry of Electronics and Information Technology* (Web Page) < https://www.meity.gov.in/>.
[9] *Centre for Development of Advanced Computing* (Web Page) <https://www.cdac.in/index.aspx>.
[10] *Ministry of External Affairs* (Web Page) <https://www.mea.gov.in/>.
[11] *The Prime Minister's Science, Technology and Innovation Advisory Council* (Web Page) <https://www.psa.gov.in/pm-stiac>.
[12] *Department of Space/Indian Space Research Organisation* (Web Page) <https://www.isro.gov.in/index.html>.
[13] *Department of Atomic Energy* (Web Page) <https://dae.gov.in/>.
[14] *Defence Research and Development Organisation* (Web Page) <https://www.drdo.gov.in/>.

1.1 National Quantum Mission (NQM)

- In April 2023 India approved its National Quantum Mission (NQM), committing INR 6,000 crore (USD 730 million) to the development of quantum technology for the next eight years. The NQM has four major domains -- Quantum Computing, Quantum Communication, Quantum Sensing & Metrology, and Quantum Materials & Devices. The government is setting up four R&D thematic hubs (T-hubs), one for each domain.
- The NQM also has a Quantum Entanglement Exchange (Quantum EE) program,[15] which aims to facilitate the exchange of students, researchers, and professionals in the field of quantum technologies, and has ongoing partnerships with the US and Japan.
- 'NQM has the potential to elevate the country's technology development ecosystem to a level of global competitiveness. The mission would greatly benefit various sectors including communication, health, financial, energy with applications in drug design, space, banking, security etc. The mission will also provide a huge boost to national priorities like Digital India, Make in India, Skill India and Stand-up India, Start-up India, Self-reliant India and Sustainable Development Goals (SDG).'[16]
- As of July 2023, MoS&T said that 'the framework on the funding outlay and operations to develop the quantum computing ecosystem is likely to be published by August [2023]'.[17] There hasn't been an update on this since.

1.2 Quantum Technology Roadmap

- In January 2024, MEITY announced a draft of its first Quantum Technology Roadmap.[18] Eight areas of focus have been allocated project milestones between 2023 and 2047:
  - Quantum Research and Development
  - Quantum Computing
  - Quantum Simulation
  - Cryptography and Cybersecurity
  - Quantum Communication
  - Quantum Sensing and Metrology
  - Quantum Strategic Applications
  - Quantum Standardization

Cryptography and Cybersecurity have been given the highest priority, with a completion date of 2028, while research and development efforts are expected to continue until 2047. Feedback submissions are currently being reviewed by MEITY.

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[15] Department of Science and Technology, 'International Collaborations', *National Quantum* (Web Page) <https://dst.gov.in/quantum-entanglement-exchange-programme>.
[16] Department of Science and Technology, 'National Quantum' (Web Page) <https://dst.gov.in/national-quantum-mission-nqm>.
[17] Shouvik Das, 'India to Issue Framework on $730 Mn Quantum Mission in Aug' (18 July 2023) *mint* <https://www.livemint.com/technology/tech-news/india-to-issue-framework-on-730-mn-quantum-mission-in-aug-11689675255958.html>
[18] https://www.meity.gov.in/writereaddata/files/Quantum%20Technologies%20Roadmap.pdf

1.3 Laboratories and Research Centres

- MEITY has collaborated with Amazon Web Services (AWS) to establish the Quantum Computing Applications Lab (QCAL). This lab will assist the scientific, academic, and developer communities in their R&D on quantum technologies.[19]
- **C-DOT** launched a **Quantum Communications Lab** in 2021, which developed a Quantum Key Distribution (QKD) solution capable of supporting a distance of more than 100 kilometres on standard optical fibre.[20] C-DOT had previously developed Post Quantum Cryptography Encryptors (PQCE) amongst other quantum technologies, and offers a complete portfolio of indigenous quantum secure telecom products and solutions.
- In February 2023, a joint team from **DRDO and IIT Delhi** demonstrated a Quantum Key Distribution (QKD) link.
- The Quantum Measurement and Control Laboratory (QuMaC) at **Tata Institute of Fundamental Research (TIFR)** primarily investigates quantum phenomena in superconducting circuits,[21] and has already made a 5-qubit quantum computer. TIFR is under the DAE.
- The Quantum Information and Computing (QuIC) lab at the **Raman Research Institute** (RRI), Bangalore is one of the first labs in India to manufacture and establish the usage of heralded and entangled photon sources towards various applications in quantum technologies.[22] The **lab has also collaborated with ISRO**.
- Samsung Semiconductor India Research and the **Indian Institute of Science (IISc)** signed an MoU to set up a quantum technology lab. The lab will focus on integrating cryogenic control chips with qubits, single photon sources and detectors while addressing reliability challenges in quantum technologies.[23]
- The **IIT Madras** has established the Center for Quantum Information, Communication and Computing (CQuICC) with an objective of developing secure quantum communications, including quantum key delivery, quantum random number generation, quantum sensing and metrology, as well as quantum computing-related innovations.[24]
- **IIT Bombay** has the Centre of Excellence in Quantum Information Computing Science & Technology (QuICST) for R&D in quantum simulation, computing, sensing and metrology, amongst others.[25]
- The **Indian Institute of Science, Education and Research (IISER)** Pune hosts the I-HUB Quantum Technology Foundation, which aims to harness quantum phenomena for developing advanced computing systems, as well as for more immediate applications in

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[19] *MEITY Quantum Computing Applications Lab* (Web Page) <https://quantumcomputing.negd.in/>.
[20] Press Information Bureau, 'Secretary Telecom Shri K. Rajaraman visits C-DOT; Inaugurates futuristic Quantum Communication Lab', (News, 10 October 2021) <https://www.pib.gov.in/PressReleasePage.aspx?PRID=1762590>.
[21] *Quantum Measurement and Control* (Web Page) <https://www.tifr.res.in/~quantro/>.
[22] *Raman Research Institute* (Web Page) <https://wwws.rri.res.in/quic/>.
[23] Bengaluru Bureau, 'Samsung, IISc sign MoU to set up quantum technology lab', (News, 19 October 2023) <https://www.thehindubusinessline.com/companies/samsung-iisc-sign-mou-to-set-up-quantum-technology-lab/article67438414.ece>.
[24] *Center for Quantum Information, Communication and Computing* (Web Page) <https://quantum.iitm.ac.in/>.
[25] *Centre of Excellence in Quantum Information Computing Science & Technology* (Web Page) <https://www.quicst.org/>.

precision sensors, navigation devices for global positioning systems, geological mapping, atomic clocks, encrypted communication, and novel materials.[26]

- **Harish-Chandra Research Institute (HRI)** is an autonomous institute funded by DAE and conducts research on quantum communication, quantum cryptography, realizable quantum computing devices, especially ultra-cold gases and quantum optical systems, and foundations of quantum mechanics.[27]
- **IISc** Bangalore has a Centre for Excellence in Quantum Technology. This centre aims to deliver quantum enhanced technologies. Its experimental program will focus on superconducting qubit devices, single photon sources and detectors for quantum communications, integrated photonic quantum networks, and quantum sensors.[28]
- The **Indian Army**, with support from the National Security Council Secretariat (NSCS) established the Quantum Lab at Military College of Telecommunication Engineering, Mhow (Madhya Pradesh) in 2021.[29]
- In 2021 **Quantum Computer Simulator Toolkit (QSim)** was launched, to enable researchers and students to carryout research in quantum computing in a cost-effective manner. QSim is an outcome of the project 'Design and Development of Quantum Computer Toolkit (Simulator, Workbench) and Capacity Building', which is being executed collaboratively by IISc Bangalore, IIT Roorkee and C-DAC with the support of MEITY.[30]
- In August 2023, the Uttar Pradesh (UP) state government signed an MoU with Innogress, a project promoter, for the Indraprastha Quantum Data Center (IQDC). The data centre is planned to have a million-qubit-powered quantum computer.[31]

1.4 Private Sector

- The Centre for Quantum Engineering, Research and Education (CQuERE) at **The Chatterjee Group Centre for Research and Education in Science & Technology (TCG CREST)** is dedicated to carry out research in quantum computation and information, and train researchers and academia in India and internationally.[32]
- **Infosys** Quantum Living Labs leverages quantum technology for its business consulting services.[33]
- **QNu Labs** is a cybersecurity company credited to be the first firm in India to successfully develop commercial cybersecurity products using quantum physics. Its subsidiary, QNu Labs Inc, was set up in Massachusetts, US in 2019.[34]

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[26] *I-HUB Quantum Technology Foundation* (Web Page) <https://www.quantech.org.in/>.
[27] *Harish-Chandra Research Institute* (Web Page) <https://www.hri.res.in/>.
[28] *Centre for Excellence in Quantum Technology* (Web Page) <https://ceqt.iisc.ac.in/>.
[29] Press Information Bureau, 'Indian Army Establishes Quantum Laboratory at Mhow (MP)', (News, 29 December 2021) <https://pib.gov.in/PressReleasePage.aspx?PRID=1786012>.
[30] Press Information Bureau, 'QSim – Quantum Computer Simulator Toolkit launched today', (News, 27 August 2021) <https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1749667>.
[31] Georgia Butler, 'India to get "million qubit" quantum computing-focused data center', *HPC & Quantum* (News, 14 August 2023) <https://www.datacenterdynamics.com/en/news/india-to-get-million-qubit-quantum-computing-focused-data-center/#:~:text=Greater%20Noida%20in%20India%20is,Quantum%20Data%20Center%20(IQDC)>.
[32] *Centre for Quantum Engineering, Research and Education* (Web Page) <https://www.tcgcrest.org/institutes/cquere/>.
[33] *Infosys Quantum Living Labs* (Web Page) <https://www.infosys.com/services/incubating-emerging-technologies/insights/quantum-living-labs.html>.
[34] *QNu Labs* (Web Page) <https://www.qnulabs.com/>.

- **BosonQ Psi** is a software venture that leverages the power of Quantum computing to perform simulations. It is the first start-up in India to join the IBM Quantum Network.[35]
- Qkrishi works to reshape the finance industry and redefine business models through the power of quantum computing. It has signed an MoU with IIT Kottayam to conduct research in quantum finance. It has also partnered with the SRM Institute of Science and Technology (SRMIST) to set up the SRMIST Qkrishi Centre of Excellence in Quantum Information and Computing (SQ-QuIC).[36]
- Mphasis provides quantum solutions and has a patent pending, EON (Energy Optimized Network), a classical-quantum hybrid network consisting of energy optimization, quantum circuit and deep neural network layers.[37]
- QuLabs,[38] Qpiai,[39] and QRDLab[40] are also at the forefront of India's quantum technology-related research and business solutions.

India has also entered several **international collaborations** for mutually beneficial development of quantum technology. These are detailed in Q14.

Although what India has done does not extend to law or regulation, the above steps could influence the formulation of future regulations.

It should be noted that a defined roadmap for the NQM is yet to be released by the government. In October 2023 the Principal Scientific Advisor (PSA) to the Centre, Ajay Sood stated that DST will put 'an appropriate structure for it [NQM] in place'.[41]

2. How is India approaching quantum technology in strategy and policy?

- India's approach is heavily focused on research and development, as seen in Q1.
- The NQM also promotes industry growth within the country, such as incubating start-ups, training programmes for new talent in the quantum workforce and growth of this workforce.[42]
- While India aims to become one of the leading nations in quantum technology, it acknowledges the necessity of working with other countries, 'the mission will generate several indigenously developed technologies but in an increasingly globalized world, a careful balance must be struck between a push for self-reliance and quick access to much needed (and easily available) global resources'.[43] Its active participation in international collaborations include dialogue about international standardisation of quantum technologies (discussed in Q9) to bilateral partnerships across R&D, academia, and trade (discussed in Q14).

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[35] *BosonQ Psi* (Web Page) <https://www.bosonqpsi.com/>.
[36] Qkrishi (Web Page) <https://qkrishi.com/about>.
[37] *Mphasis* (Web Page) <https://www.mphasis.com/home.html>.
[38] *QuLabs* (Web Page) <https://www.qulabs.ai/about.html>.
[39] *Qpiai* (Web Page) <https://qpiai.tech/>.
[40] *QRDLab* (Web Page) <https://www.qrdlab.in/overview>.
[41] Shouvik Das, 'India's quantum mission geopolitically key, to be actualized soon', (News, 5 October 2023) <https://www.livemint.com/news/india/indias-quantum-mission-geopolitically-key-to-be-actualized-soon-11696526031816.html>.
[42] Department of Science and Technology, 'The National Quantum Mission: An unprecedented opportunity for India to leapfrog in quantum computing technologies', (Web Page) <https://dst.gov.in/national-quantum-mission-unprecedented-opportunity-india-leapfrog-quantum-computing-technologies>.
[43] Ibid.

- Quantum technology is mentioned in regulations regarding foreign trade and standardisation. Although R&D plans are in motion, the execution and regulation of it and its outcomes is not yet known.

3. What technologies are mentioned in India's quantum strategy and policy?

- The NQM is expected to have a significant impact on various sectors including communication, health, finance, energy, drug design, and space applications.[44] It has four major domains -- Quantum Computing, Quantum Communication, Quantum Sensing & Metrology, and Quantum Materials & Devices.
- It targets to develop intermediate-scale **quantum computers with 50-1000 physical qubits** within eight years, using various platforms such as **superconducting and photonic technology**. It also aims to establish **satellite-based secure quantum communications** between ground stations within India and with other countries over a range of 2,000 kilometers, as well as **inter-city quantum key distribution** over 2,000 kilometers and **multi-node Quantum network with quantum memories.**
- The mission will also focus on developing **high-sensitivity magnetometers in atomic systems and Atomic Clocks** for precision timing, communications, and navigation. Additionally, it will support the **design and synthesis of quantum materials such as superconductors, novel semiconductor structures, and topological materials** for fabrication of quantum devices. **Single photon sources/detectors and entangled photon sources** will be developed for quantum communications, sensing, and metrological applications.[45]

4. What competition/competing interests are mentioned/raised/identified in India's quantum strategy and policy?

India aims to be a leader in quantum technology, represented by such commentary:

- India's PSA has said that NQM will be 'crucial in geopolitical strategies'.[4]
- The Indian government has stated that currently India 'trails considerably behind China and the United States' but is making steady moves towards achieving quantum supremacy ('moves' as enlisted in Q1).[5]
- Referring to the initiatives listed in Q1, the government has stated that these have taken India a 'step closer towards achieving quantum readiness' and that India is 'ready to take the lead in quantum tech'.[6]
- The Additional Secretary, MEITY, Rajendra Kumar said, 'A**n early and successful foundation in quantum computing is important to achieve leadership in this emerging field.** The MEITY QCAL, established with the support of AWS, is the **first of its kind initiative in the world**, and aims to enable India's talented researchers to explore the unchartered applications of quantum computing, and pave the way for new discoveries and disruptions'.[7]
- Minister of Science & Technology, Dr Jitendra Singh recently said the NQM will make India one of the top global leaders in areas like quantum computing, quantum communication, quantum sensing, quantum materials, metrology and devices.[46]

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[44] Matt Swayne, 'India Announces $730 Million-Plus National Quantum Mission', (News, 20 April 2023) <https://thequantuminsider.com/2023/04/20/india-announces-730-million-plus-national-quantum-mission/>.
[45] Press Information Bureau, 'Cabinet approves National Quantum Mission to scale-up scientific & industrial R&D for quantum technologies', (News, 19 April 2023) <https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1917888>.
[46] Press Information Bureau (n 3).

- A 2022 NASSCOM-Avasant report on India's quantum supremacy stated that, 'in noisy intermediate-scale quantum (NISQ) era the number of quantum bits is too small (50-100 qubits) and lack error correction to perform complex computations but large enough to demonstrate quantum advantage.'[47]

At the same time, as seen in Q14, India is actively collaborating with several countries, so it can be inferred that while India aims to be a leader in quantum technology, it seeks to do so collaboratively rather than competitively at the global stage.

While it has not been communicated how India intends to become a leader in quantum technology / achieve quantum supremacy or advantage, it may be implied that the many domestic and international initiatives for quantum R&D will pave the way for this goal.

Additionally, indirectly quantum technologies are included in India's dual-use list, and may be protected under the import-export and foreign investment policies in cases where quantum technology is used for defence goods and services. However, competing interests are not mentioned within the NQM.

5. Is there consideration of the impact of quantum computing and quantum communications?

Other than the technological and economic benefits mentioned in Q1, the impact of quantum computing and communications has not been addressed.

6. Does India's approach to quantum consider/mention quantum-safe encryption, quantum cryptography?

Yes, as mentioned in Q3 Quantum Communications is one of the four main domains under NQM, and quantum cryptography is included in this.

Further details are mentioned in Q7.

7. What does India's approach to quantum technology say about current encryption practices and processes? Does it mention that quantum will 'break' current encryption?

India has developed the following in furtherance of its quantum communications:

- ISRO demonstrated free-space quantum communication over a distance of 300 metres, with the claim that, 'quantum cryptography is considered as 'future-proof', since no future advancements in the computational power can break quantum-cryptosystem.'[48]
- In February 2023, a joint team from DRDO and IIT Delhi demonstrated Quantum Key Distribution (QKD) link between the cities Prayagraj and Vindhyachal in Uttar Pradesh, across a distance of more than 100 kilometres.[49]
- In March 2023 the GOI announced that the first quantum secure communication link is active between the Department of Telecommunications (DoT) and the National

[47] NASSCOM-AVASANT, 'The quantum revolution in India: Betting big on quantum supremacy', (Report, February 2022) < https://nasscom.in/knowledge-center/publications/quantum-revolution-india-betting-big-quantum-supremacy>.
[48] Indian Space Research Organisation, 'ISRO makes breakthrough demonstration of free-space Quantum Key Distribution (QKD) over 300 m', *Media* (Web Page) <https://www.isro.gov.in/Quantum%20Key%20Distribution%20(QKD).html>.
[49] Press Information Bureau, 'DRDO and IIT Delhi scientists demonstrate Quantum Key Distribution between two cities 100 kilometres apart', (News, 23 February 2022) <https://pib.gov.in/PressReleasePage.aspx?PRID=1800648>.

Informatics Centre (NIC).[50] C-DoT has said that '**the traditional key-based cryptography has become vulnerable for attacks...to protect the channels from such attacks post-quantum cryptography is picking up**'.[51]

- CQuICC is developing quantum key delivery.
- The I-HUB Quantum Technology Foundation aims to harness encrypted communication

It is evident that cryptography is an integral part of India's NQM. The focus is on developing quantum communication systems, and apart from general discussion about the possibility of quantum computers breaking current encryption,[52] the NQM does not address the latter.

8. Does India's approach to quantum mention any specific regulatory or legal frameworks? If so, which frameworks? If so, what is the predicted impact of quantum on those frameworks? If so, does the approach outline any possible solutions?

As mentioned in the strategy and policy discussion, India has several ministerial divisions overseeing the development of quantum technology. However, it is yet to put into effect any regulatory or legal frameworks. The proposed **Digital India Act (DIA) 2023**[53] seeks to enforce 'global standard cyber laws' which will have seven objectives, one of which is to 'address emerging technologies and risks'. Further, one of the goals of the DIA is that 'the new law should evolve through rules that can be updated, and address the tenets of Digital India', and one of these tenets is 'new technologies'. It mentions 'Open Internet' as a key component, which enlists an aim to, 'Safeguard innovation to enable emerging technologies like AI/ML... **Quantum Computing**...Natural-language processing, etc.'. Currently, the proposed legislation has not provided further details on how India will approach quantum and related technologies.

It may be noted that the DIA is set to replace the Information Technology Act 2000[54] (revised in 2008 and 2011), because the latter is 'old and dated' and 'provisioned for nascent IT ecosystem in 2000 pre-Digital India in the absence of modern internet-based service such as e-Commerce, social media platforms'.[55] Thus, the new Act will address the modern-day digital technology issues.

Moreover, India is in the process of introducing new regulatory and legal frameworks across the spectrum of data and digital technology. In furtherance of the same, it recently passed the Digital Personal Data Protection (DPDP) Act 2023[56] in August, the Intermediary Rules 2022,[57] and the Consumer Protection (E-commerce) Rules 2020. It is also considering enacting several other laws, such as the Digital Competition law (speculated to follow the EU Digital Markets Act), the Non-personal Data Framework, and Online Gaming (Regulation) Bill 2022. While there is no explicit mention of quantum technology in relation to these, India's parallel development of emerging technologies and digital regulations may cause the two to intersect at some point in the future.

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[50] Yuthika Bhargava, 'Govt launches 'quantum communication' network with a dare: Rs 10L for ethical hackers who can break encryption', *Governance* (News, 27 March 2023) <https://theprint.in/india/govt-launches-quantum-communication-network-with-a-dare-rs-10l-for-ethical-hackers-who-can-break-encryption/1476283/>.
[51] C-DoT, 'First International Quantum Communication Conclave' (Web Page) <https://cdot.in/cdotweb/web/quantumConclave23.php>.
[52] Department of Science and Technology (n 42).
[53] Ministry of Electronics and Information Technology, 'Proposed Digital India Act 2023', *Digital India Dialogues* (9 March 2023) <https://www.meity.gov.in/writereaddata/files/DIA_Presentation%2009.03.2023%20Final.pdf>.
[54] *Information Technology Act 2000* (India).
[55] Ministry of Electronics and Information Technology (n 53) 2.
[56] *Digital Personal Data Protection Act 2023* (India).
[57] *The Information Technology (Intermediary Guidelines and Digital Media Ethics Code) Rules 2021* (India).

Lastly, India enforced the Anusandhan National Research Foundation Act, 2023[58] this year. The bill establishes the National Research Foundation (NRF), which will be the apex body in the country to provide strategic direction for research, innovation, and entrepreneurship in the fields of natural sciences including mathematics, engineering and technology, environmental and earth sciences, health and agriculture, and scientific and technological interfaces of humanities and social sciences. NRF will be funded by government as well as non-government resources.[59] Given its scope, it is likely that NRF will create provisions for quantum technology in the future.

9. Are there any international or national standards identified in India's approach to quantum technology? If so, what are they and where do they come from?

- The Bureau of Indian Standards (BIS) is the national standards body of India, it develops standardization, marking, and quality certification of goods and services. Presently, in relation to critical technologies the BIS has published standards for 'Semiconductor and Other Electronic Components and Devices'.[60] The Electronics and IT Division Council (LITDC),[61] under BIS, is primarily responsible for developing Indian Standards in the field of Electronics and IT products, and has a technical committee for quantum computing.[62]
- The BIS has undertaken the Standards National Action Plan (SNAP) 2022-27[63], launched in January 2023, it will steer the national efforts for standards, certifications, and the specifications for future emerging technologies, amongst other sectors.[64] SNAP identifies 'Digital Engineering and other Enabling Technologies' as one of the primary drivers of future standardisation, and these enlist quantum computing as one of the emerging technologies which will be addressed.
- The International Organization for Standardization (ISO) / International Electrotechnical Commission (IEC) Joint Technical Committee (JTC 1) is a consensus based, voluntary international standards group focussing on information technology (IT). India is a member of its Working Group (WG) 14, it serves as a systems integration entity to focus on JTC 1's standardization program on Quantum Computing and maintain relationships with other related ISO and IEC/TCs and other organizations. The responsibility of WG 14 is to identify gaps and opportunities and develop deliverables in the area of Quantum Computing.[65]

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[58] *Anusandhan National Research Foundation Act 2023* (India).
[59] Press Information Bureau (n 3).
[60]Bureau of Indian Standards, 'Published Standards: (LITD)', (Web Page) <https://www.services.bis.gov.in/php/BIS_2.0/dgdashboard/published/subcommtt?depid=NjY%3D&aspect=&doe=&dt_from=&dt_to=>.
[61] Electronics and IT Division, Bureau of Indian Standards, 'Strategic Roadmap', (Web Page) <https://www.services.bis.gov.in/tmp/ELECTRONICS%20AND%20IT%20DIVISION%20COUNCIL.pdf>.
[62]Bureau of Indian Standards, 'LITD C : P5 - Quantum Computing Panel', (Web Page) <https://www.services.bis.gov.in/php/BIS_2.0/bisconnect/dgdashboard/committee_sso/composition/604/4>.
[63] Bureau of Indian Standards, 'Standards National Action Plan (SNAP) 2022-27', 55 <https://www.bis.gov.in/wp-content/uploads/2023/05/SNPbookBilingual.pdf>.
[64] Press Information Bureau, 'India must recognize and accept the importance of quality to become a developed nation: Shri Piyush Goyal', (News, 6 January 2023) <https://pib.gov.in/PressReleseDetailm.aspx?PRID=1889301#:~:text=Launch%20of%20Standards%20National%20Action,of%20sustainability%20and%20climate%20change>.
[65] ISO-IEC Joint Technical Committee, 'ISO/IEC JTC 1/WG 14 Quantum Information Technology', *WG 14* (Web Page, November 2022) <https://jtc1info.org/sd-2-history/jtc1-working-groups/wg-14/#:~:text=Quantum%20Information%20Technology&text=In%20June%202020%2C%20WG%2014,IEC%2FTCs%20and%20other%20organizations>.

- India is a member of the Quantum Economic Development Consortium (QED-C), which supports the formation of the proposed ISO/IEC Joint Technical Committee on Quantum Technologies (JTC-Q).[66]
- India is also a member of International Telecommunication Union (ITU). In March 2021 ITU, in collaboration with the IEC, the Institute of Electrical and Electronics Engineers (IEEE) UK and Ireland Photonics Chapter, organised a Joint Symposium on Standards for Quantum Technologies.[67] 'The discussion aims to establish panelists' opinion on the appropriate shape of 'standardization roadmap' for quantum information technologies'.

India has effectuated national standards for semiconductors, but for any other critical technology the formulation of national standards is underway. India is also actively involved in the international dialogue on standardisation of quantum computing, and is likely to incorporate those standards into its national plan, because one of the SNAP objectives is to align Indian standards with international standards.[68]

10. Does India's approach to quantum technology discuss barriers or challenges of quantum technology? If so, what are they? What will be affected?

The government's approach has not outlined the challenges that may be faced during the development of quantum technologies. However, a 2019 draft concept note by the Technology Information, Forecasting and Assessment Council (TIFAC) discussed three national gap areas in India's quantum strategy:

- Lack of resources for higher education
- Increase university-level adoption: If India wants to build a quantum-ready workforce and compete at a global stage, it will have to develop quantum science and engineering as its own discipline at the graduate level. This will have to be coupled with new faculty and deepening engagement with industry players. This would also require an increased investment in setting up QT research centres in public-private partnerships. Also, the Government will have to play a proactive role in generating awareness about quantum science at secondary school level.
- To capitalise on quantum computing, India needs to build the required technical infrastructure[69]

11. Does India's approach to quantum technology discuss critical technology and dual-use regulatory and legal frameworks?

India's quantum approach itself does not discuss critical technology and dual-use regulatory and legal frameworks. At the same time, it's export control regulation of dual-use goods and services, which exists separately from India's quantum strategy, does include critical technologies like quantum, cryptography, and encryption. This has been detailed in Q13.

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[66] QED-C, 'Support for the Formation of the ISO/IEC Joint Technical Committee for Quantum Technologies (JTC-Q)', *News & Events* (Web Page, 30 August 2023) <https://quantumconsortium.org/support-for-the-formation-of-the-iso-iec-joint-technical-committee-for-quantum-technologies-jtc-q/>.
[67] ITU, 'Joint Symposium on Standards for Quantum Technologies', (Web Page) <https://www.itu.int/en/ITU-T/Workshops-and-Seminars/2021/0323/Pages/default.aspx>.
[68] Bureau of Indian Standards (n 63) 59.
[69] Technology Information, Forecasting and Assessment Council, 'Draft Concept Note National Mission on Quantum Technology & Applications (NM-QTA)', 6-7 <https://tifac.org.in/images/nmqta/concept_note12.06.19.pdf>.

It can be observed that the country's quantum mission has not established any legal or regulatory frameworks for dual-use goods and services in the quantum sector, however, protection is extended to these indirectly via India's foreign trade regulation.

12. Are there any gaps identified in India's approach to quantum technology? Are there any barriers and challenges identified in India's approach? Are there any advantages to India's approach?

In its endeavour to power through to becoming a world leader in quantum technology, India has **prioritised its R&D initiatives and international collaborations**. This will be **advantageous** for becoming an innovation hub for quantum technologies and harnessing international relations for mutually beneficial development and use of these technologies. At the same time, **policy, regulatory and legal frameworks are lacking**, and without this support the growth and use of quantum technology can be uncertain. The **gaps identified** in India's approach are listed as under:

- The government's communication of NQM comprises of press updates including generic goals and methods to achieve those. Detailed and quantifiable information regarding the objectives and pathways to attain those is required
- The discussion for NQM did not invite inputs from experts across academia and industry. Opening the discussion can help tackle on-ground problems and advance the commercialisation of quantum technology
- As noted in Q2, Q4, and Q10, India has not yet defined the competing interests, considered the impact of quantum computing, and the challenges faced by its quantum technology sector. The NQM should outline these to facilitate a sharper vision of status quo, intended result, and a roadmap for it
- Investment, standardisation, dual-use, and import-export regulation in relation to quantum technologies is being addressed in India, however, this is via the separate bodies which oversee these frameworks, creating a piecemeal approach. A consolidated approach under the NQM, which addresses (or attempts to address) all regulatory and legal factors related to quantum technology is lacking
- Following from the previous point, unlike countries like the US and Australia, India has not established a separate governing body for its quantum mission. The NQM is being carried out by various government ministries and departments, as discussed in Q1. This scattered implementation can cause delayed processing, non-uniform guidelines, gratuitous competition amongst departments, which can be avoided if there is a single governing body for India's quantum approach

Further, the Observer Research Foundation (ORF) has put forth possible **challenges** to India's quantum mission.[70] This report was published before the NQM was announced, but the challenges are likely to remain unchanged:

- **Funding:** the budget for India's quantum strategy is not being allocated separately for the mission, but will be extracted from the annual allocation made to different central ministries and departments. For example, the DST will have to draw out funds from its annual financial statement for its experiments for the mission.[71]

[70] Prachi Mishra, Observer Research Foundation, 'India's Challenges and Opportunities in the Quantum Era', (Report, 14 April 2023) < https://www.orfonline.org/wp-content/uploads/2023/04/orf_report_quantum.pdf>.
[71] Ibid 46.

- Current **import policy** does not allow for quick and easy access to global quantum hardware and software technologies, which are needed to develop India's indigenous quantum sector.[72]
- India has **limited investment** for manufacturing quantum hardware within the country[73]
- To exert tech sovereignty, India not only has to produce hardware but also **scale quantum computing to commercial levels.** However, India's **investment and funding is not at par with countries like US and China**, the **private sector's involvement** is not as requisite as needed, and a **lack of policies** and investment that boost local manufacturing of electronic equipment has been an ongoing problem in India.[74]
- India's quantum computing needs more academics and support staff, increased industry-academia liaising, and reducing the education and skills gap.[75]
- India needs to **support innovation** by creating patent offices in universities, seamless sanctioning of labs to new scientists, open innovation platforms, and well-defined metrics to gauge progress.

Thus, as India takes strides in developing quantum technology indigenously and collaboratively, it needs to administer appropriate policies which help support and streamline the outcomes of its R&D.

13. Summarise dual-use and investment regulation for quantum technologies.

The Foreign Trade (Development & Regulation) Act, 1992[76] provides for the development and regulation of India's international trade. The Directorate General of Foreign Trade (DGFT) publishes the Foreign Trade Policy (FTP), which governs the exports and imports of goods and services.

As per India's FTP 2023, 'export of dual-use items, including software and technologies, having potential civilian / industrial applications as well as use in weapons of mass destruction is regulated. It is either prohibited or is permitted under an authorization unless specifically exempted.'[77] The dual-use items are mentioned in the SCOMET (Special Chemicals, Organisms, Materials, Equipment and Technologies) list, which includes software and technology. In relation to quantum and critical technologies, this list mentions:

- Cryptographic activation
- Cryptography
- Cryptanalysis (under Information Technology)
- Quantum Cryptography
- Quantum Key Distribution (QKD)
- Superconducting Quantum Interference Device (SQUID)
- Symmetric and Asymmetric Algorithms for encryption/decryption

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[72] Mishra (n 70) 47.
[73] Ibid.
[74] Mishra (n 70) 50
[75] Mishra (n 70) 52-54
[76] *Foreign Trade (Development & Regulation) Act 1992* (India).
[77] Directorate General of Foreign Trade, 'Chapter 10: Special Chemicals, Organisms, Materials, Equipment and Technologies'. *Foreign Trade Policy 2023* <https://content.dgft.gov.in/Website/dgftprod/a2f58730-df83-49df-a437-b5f6345abb66/FTP2023_Chapter10.pdf>.

Examples include:

- 8A502: '"Information security" systems, equipment and components designed or modified to use (a)'**cryptography for data confidentiality**'…or (c) perform "**quantum cryptography**"...'
- 8E303(b): 'Other "technology" for the "development" or "production" of hetero-structure semiconductor electronic devices such as high electron mobility transistors (HEMT), hetero-bipolar transistors (HBT), **quantum well and super lattice devices**'.

The FTP 2023 also states catch-all controls for any dual use items not mentioned in the SCOMET list, which may be regulated by the Weapons of Mass Destruction and their Delivery Systems (Prohibition of Unlawful Activities) Act, 2005.[78] This could be applied to critical technologies which may be used for WMD in the future.

India is a signatory to the major Multilateral Export Control Regimes (MECR), namely, Missile Technology Control Regime (MTCR), Wassenaar Arrangement (WA) and Australia Group (AG), and adherent to Nuclear Supply Group (NSG). India is also a signatory to international conventions on non-proliferation, namely, Chemical Weapons Convention (CWC) and Biological and Toxic Weapons Convention (BWC). Accordingly, the SCOMET control list is aligned to the control lists of all four MECR and both conventions.

When it comes to the import policy, the government's list of 'Restricted Items for Import' could be used to deduce that certain products where quantum technology could be used are not permitted except when those have a government license, like communication jamming equipment, satellite communication equipment, marine radio communication equipment, etc. However, there is no explicit mention of quantum or critical technologies.

A look at India's position at importing quantum technology, apart from existing regulation, presents a mixed opinion. On one hand officials within MEITY have commented on the topic that, 'importing or purchasing the technology is not a sustainable solution in the long term. India needs to develop the capabilities for this technology internally...'[79]. On the other hand, the DST has stated on separate occasions that, ' We believe materials and devices-based innovation will create new businesses from manufacturing supporting equipment, which India now needs to import, to high-end specialized devices, such as semiconductor-based single photon detectors, at the bulk scale.'[80] and 'Delays in funds disbursal and other impediments like restrictions on import of critical enabling technologies must be removed to enable rapid progress and prevent wastage of time and resources.'[81] Furthermore, TCG CREST is building a quantum computer in India and has already imported a dilution refrigerator from Finland as the first building block for its hardware.[82]

Thus, it can be gathered that India's export policy of dual-use and defence goods substantially regulates quantum technology. At the same time, the import policy is lacking in

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[78] *Weapons of Mass Destruction and their Delivery Systems (Prohibition of Unlawful Activities) Act 2005* (India).
[79] Ojasvi Nath, 'Quantum Tech's Promising Growth Post Govt Initiative', (News, 3 June 2021) <https://www.businessworld.in/article/Quantum-Tech-s-Promising-Growth-Post-Govt-Initiative/03-06-2021-391922/>.
[80] Department of Science and Technology, 'Material Opportunities for India's Quantum Technology Mission', (Web Page) <https://dst.gov.in/material-opportunities-indias-quantum-technology-mission>.
[81] Department of Science and Technology, 'The National Quantum Mission: An unprecedented opportunity for India to leapfrog in quantum computing technologies', (Web Page) <https://dst.gov.in/national-quantum-mission-unprecedented-opportunity-india-leapfrog-quantum-computing-technologies>.
[82] Matt Swayne, 'India's The Chatterjee Group, Partners to Build Quantum Computer', *Quantum Computing Business, Research* (Web Page, 1 May 2023) <https://thequantuminsider.com/2023/05/01/indias-the-chatterjee-group-partners-to-build-quantum-computer/>.

this aspect. It also appears that while India is aiming to be an exporter of quantum software, it needs and plans to import hardware in order to develop said software.

13.1 Foreign Investment

India's Foreign Direct Investment (FDI) is overseen by the Department for Promotion of Industry and Internal Trade (DPIIT) under the Ministry of Commerce and Industry, and it is governed by the Foreign Exchange Management Act, 1999 (FEMA). The current FDI Policy has been effective since 2020 and does not include guidelines on quantum technology. It is likely that until specific regulation for FDI on critical technologies is developed, these will follow the existing rules for the Information Technology sector.

India allows 100 percent FDI in the IT sector[83], and is the country to receive the most foreign investment in data centres since 2019[84]. Foreign venture capital investors (FVCIs) are permitted to invest in many sectors, including software and information technology.[85] India also has Software Technology Parks (STPs), which are special zones for incentives for foreign investors in software export-oriented businesses. Once again, although no detailed discussion around critical technologies exists in relation to foreign investment, there has been a fleeting mention of quantum technologies in the draft Data Centre Policy 2020 by MEITY. As noted above, Indian data centres receive the world's biggest share of FDI, and MEITY refers to growing these data centres by the adoption of "emerging technologies such as quantum computing".[86]

Additionally, the FDI Policy allows foreign investment either via the automatic route (no government approval needed) or via the government approval route. Eleven sectors require government approval: Mining, Defence/cases relating to FDI in small arms, Broadcasting, Print media, Civil Aviation, Satellites, Telecom, Private Security Agencies, Trading (Single, Multi brand and Food Products), Financial services not regulated or regulated by more than one regulator/Banking Public and Private (as per FDI Policy) and Pharmaceuticals.[87] So, if the quantum technology-based foreign investment is any of these sectors, it will require a government permit, unlike the 100 percent allowance for IT sector.

Finally, it can be observed that India's policy on foreign investment does not provide well-defined guidelines for quantum technology. This is juxtaposed with the country's multiple international collaborations on quantum technology, few of which entail foreign investment in India.[88] Thus, it appears that while India's trade is prepared for foreign investment, its policies are yet to catch up with the quantum industry.

14. Has India partnered with other countries for developing quantum technology?

Yes, India has entered into several international partnerships on quantum technology. These are listed as under:

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[83] Legal Window, 'Guidelines on FDI in Information Technology Sector in India', (Web Page, 1 March 2021) <https://www.legalwindow.in/guidelines-on-fdi-in-information-technology-sector-in-india/>.
[84] Sebastian Shehadi, 'India is top global destination for foreign investment in data centres', (News, 27 September 2023) <https://www.investmentmonitor.ai/news/india-data-centres-fdi-leading-global-germany/>.
[85] Bureau of Economic and Business Affairs (US), '2021 Investment Climate Statements: India', (Report) <https://www.state.gov/reports/2021-investment-climate-statements/india>.
[86] Ministry of Electronics & Information Technology, 'Data Centre Policy 2020', (Draft) 1.3 <https://www.meity.gov.in/writereaddata/files/Draft%20Data%20Centre%20Policy%20-%2003112020_v5.5.pdf>.
[87] Foreign Investment Facilitation Portal, 'Present FIFP', (Web Page) <https://fifp.gov.in/AboutUs.aspx>.
[88] US Department of Defense, 'Joint Statement on the Fifth Annual India-U.S. 2+2 Ministerial Dialogue', *Release* (Press Release, 10 November 2023) < https://www.defense.gov/News/Releases/Release/Article/3586228/joint-statement-on-the-fifth-annual-india-us-22-ministerial-dialogue/#:~:text=The%20Ministers%20welcomed%20the%20rapid,in%20New%20Delhi%20in%20early>.

14.1 India-US collaboration

1) **Initiative on Critical and Emerging Technology (iCET):** Both countries signed the iCET in January 2023, a bilateral initiative which harbours cooperation between their governments, industry, and academia. The initiative spans across sectors like defence, space, telecommunications; and in relation to quantum technology, it entails the following:

- establishing a joint Indo-US Quantum Coordination Mechanism to facilitate research and industry collaboration
- signing a new Implementation Arrangement for a Research Agency Partnership, to expand international collaboration in a range of areas including quantum technologies
- the U.S. Department of Defense (DoD) and the Indian Ministry of Defense (MoD) launched the India-U.S. Defense Acceleration Ecosystem (INDUS-X) to expand the strategic technology partnership and defence industrial cooperation

2) IIT Bombay has joined the **Chicago Quantum Exchange** as an international partner.

3) India and the US have signed an **MoU** between Indian universities, represented by the IIT Council, and the Association of American Universities (AAU) to establish the **India-US Global Challenges Institute**, with a combined initial commitment of at least USD 10 million. The Global Challenges Institute will advance new frontiers in science and technology, spanning collaboration in semiconductor technology and manufacturing and quantum science, amongst other industries.

4) They have a **growing number of multi-institutional collaborative education partnerships**, such as those between New York University-Tandon and IIT Kanpur Advanced Research Center, and the Joint Research Centres of the State University of New York at Buffalo and IIT Delhi, Kanpur, Jodhpur, and BHU, **in the areas of critical and emerging technologies.**

5) Both countries have signed an **MoU on Semiconductor Supply Chain and Innovation Partnership**. The **combined investment is valued at USD 2.75 billion**, with Micron Technology Inc., to invest up to USD 825 million to build a new semiconductor assembly and test facility in India and Applied Materials Inc., to invest USD 400 million to establish a collaborative engineering centre in India.

6) They have launched a **USD 2 million grant** program under the **U.S.-India Science and Technology Endowment fund** for the joint development and commercialization of AI and quantum technologies, and encouraged public-private collaborations to develop high performance computing (HPC) facilities in India.

7) The **US-based IBM has signed an MoU with three MEITY entities** for advancing India's comprehensive strategy for AI, strengthen efforts to be self-reliant in semiconductors and advance its National Quantum Mission. These MoUs have been signed between IBM and MEITY's INDIAai, India Semiconductor Mission (ISM) and C-DAC.[89]

[89] Nidhi Singal, 'IBM, MeitY sign MoUs to advance innovation in AI, semiconductor and quantum innovation in India', (News, 18 October 2023) <https://www.businesstoday.in/latest/in-focus/story/ibm-meity-sign-mous-to-advance-innovation-in-ai-semiconductor-and-quantum-innovation-in-india-402508-2023-10-18>.

8) India's Tata Consulting Services (TCS) has as launched the TCS Quantum Computing Lab on US-based AWS to help enterprises explore, develop, and test business solutions and accelerate the adoption of quantum computing.[90]

14.2 India's partnerships with other countries

1. India is already engaged with **Entanglement Exchange** and the **US QED-C** enabling multi-nation exchanges on quantum computing.
2. **EU-India Trade and Technology Council:** Launched in February 2023, the TTC seeks to increase EU-India bilateral trade. The European Union and India will cooperate on **quantum and High-Performance Computing research and development projects** to help address challenges such as climate change and natural disasters and improve healthcare via personalised medicine. They will also coordinate their policies with regards to the strategic **semiconductors** sector through a dedicated **MoU**.
3. **DESI initiative by Finland:** The Digitalisation, Education, Sustainability and Innovation (DESI) initiative aims to 'combine the strengths of both countries to create new business opportunities, drive innovation, and build a more sustainable future for all.' The DESI Initiative together with the Team Finland network and the Finnish business and science community, Finnish top expertise from all sectors will be gathered under one umbrella. This is **Finland's first export promotion program and seeks to be a part of India's economic growth by providing Finnish expertise on quantum technology** and other sectors. Additionally, India's **HCLTech and Business Finland** have signed a **MoU** to collaborate on quantum technology, AI, and space technology.
4. **HCL Tech has also signed an MoU with Sydney Quantum Academy** (SQA). SQA is a partnership between Macquarie University, the University of New South Wales, the University of Technology Sydney, and the University of Sydney. **SQA is supported by the New South Wales (NSW) government** with a vision to build Australia's quantum economy. Through this industry-academia partnership, **HCL Technologies and SQA aim to bring together their capabilities to create education and development opportunities for students** within the realm of quantum technology. Other opportunities, which will be explored as part of the MoU, will **connect HCL's diverse and large client base with the growing Sydney quantum community**.[91]
5. India's Tech Mahindra has signed a partnership deal with **Spain's** Multiverse Computing to bring quantum software to its enterprise clients.
6. **India's TCG CREST** has built major partnerships with the University of Tokyo and Keio University in **Japan**, the University of Wisconsin **(US)**, **Singapore's** Centre for Quantum Technologies (CQT), and **Spanish** start-up Qilimanjaro for quantum computing.
7. **India Japan Science and Technology Cooperation** is a part of India's NQM to promote bilateral scientific collaboration between Indian and Japanese scientists. Additionally, in July 2023 India and Japan agreed to **collaborate on semiconductors** to create a more resilient supply chain for this critical technology. The partnership will focus on five areas: 'semiconductor design, manufacturing, equipment research, establishing resilience in the

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[90] Tata Consultancy Services, 'TCS Joins Hands with AWS to Help Enterprises Harness the Power of Quantum Computing', (Web Pag, 28 November 2022) <https://www.tcs.com/who-we-are/newsroom/press-release/tcs-joins-hands-with-aws-help-enterprises-harness-power-quantum-computing>.

[91] HCLTech,' HCL Technologies and Sydney Quantum Academy to collaborate on quantum technology ecosystem development', (News, 29 July 2022) <https://www.hcltech.com/newsfeed/news/hcl-technologies-and-sydney-quantum-academy-collaborate-quantum-technology-ecosystem>.

semiconductor supply chain, and talent development', paving the way for government-to-government and industry-to-industry collaborations.[92]

8. The **Australia-India Cyber and Critical Technology Partnership (AICCTP)** to invest in cyber and critical tech collaborations and initiatives aims to support an open, free, rules-based Indo-Pacific region.[93]
9. India is also a member of the **Quad Critical and Emerging Technology Working Group,** a partnership between Australia, US, Japan, and India. Quad partners are working actively together to meet challenges faced by the Indo-Pacific, including in the area of critical and emerging technology.[94]

The latest meeting amongst the Quad heads of state was conducted in May 2023 in Hiroshima, Japan. The Quad has six working groups, one of those is the Critical and Emerging Technology (CET). The CET WG promotes global technology markets and standards based on openness, diversity, trust and resilience. The CET WG cooperates on technical standards; 5G; horizon scanning; and technology supply chains. Quad Leaders have agreed to work together on artificial intelligence; semi-conductor supply chains; and monitoring trends in critical and emerging technologies, including advanced biotechnologies, and Open Radio Access Networks (Open RAN).

The Quad has published a joint statement of **Principles on CET Standards**, broadly these are to 'support industry led, consensus-based multi-stakeholder approaches', 'support technology standards that promote interoperability, competition, inclusiveness and innovation', and 'foster technology standards that support safety, security and resilience'.[95]

The May 2023 meeting published the following updates for the Quad CET division:

- The Quad will develop Open RAN in Palau.
- The Quad welcomed a new report outlining cybersecurity considerations associated with using Open RAN as an approach to developing network architecture.
- Advancing Innovation to Empower Nextgen Agriculture (AI-ENGAGE) is a research collaboration that will leverage joint funding, expertise, infrastructure and other resources to deliver scientific advances to increase crop yield and resilience.
- Quad Technology Business and Investment Forum was launched in December 2022, which laid the foundation for enhanced private-public collaboration across the four governments, industry, investors, academia, and civil society on CET.

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[92] Harsh V Pant and Pratanshree Basu, 'A 'fab' way to conduct India-Japan tech diplomacy', (News, 19 August 2023) <https://www.thehindu.com/opinion/op-ed/a-fab-way-to-conduct-india-japan-tech-diplomacy/article67210701.ece>.
[93] Assistant Minister for Foreign Affairs (Australia), 'Australia-India Cyber and Critical Technology Partnership grants: Round 3', (Media Release, 31 August 2023) <https://ministers.dfat.gov.au/minister/tim-watts/media-release/australia-india-cyber-and-critical-technology-partnership-grants-round-3>.
[94] Department of Prime Minister and Cabinet (Australia), 'Quad Working Groups', (Web Page) <https://www.pmc.gov.au/quad-2023/quad-working-groups>.
[95] Department of Prime Minister and Cabinet (Australia), 'Quad Principles on Critical and Emerging Technology Standards', (Web Page) < https://www.pmc.gov.au/resources/quad-principles-critical-and-emerging-technology-standards#:~:text=They%20should%20promote%20interoperability%2C%20innovation,free%20and%20fair%20market%20competition>.

10. **Mphasis** has formed a strategic partnership with the University of Calgary and the Government of Alberta to announce the establishment of Quantum City – **Canada**.[96]

[96] Mphasis, 'Celebrating one year of Mphasis' inspiring journey in Calgary, Alberta', (Press Release, 7 September 2023) <https://www.mphasis.com/content/dam/mphasis-com/global/en/news/press_releases/celebrating-one-year-of-mphasis-inspiring-leadership-journey-in-calgary-alberta.pdf>.

15. India Quantum Acronyms

S.no.	Acronym	Body	Description
1.	MEITY	Ministry of Electronics and Information Technology	The Ministry of Electronics and Information Technology oversees policy matters relating to information technology, electronics, and internet
2.	MoS&T	Ministry of Science and Technology	The Ministry of Science and Technology promotes the excellence and reach of India's science and technology so that it can solve global problems with local relevance.
3.	DST	Department of Science and Technology	DST formulates policies relating to S&T, handles matters relating to the Scientific Advisory Committee of the Cabinet (SACC) and promotes new areas of S&T with special emphasis on emerging areas through R&D in its research institutions or laboratories.
4.	C-DAC	Centre for Development of Advanced Computing	The Centre for Development of Advanced Computing is under MEITY and carries out R&D in IT, Electronics and associated areas.
5.	C-DOT	Centre for Development of Telematics	The Centre for Development of Telematics is under MoS&T. It is an autonomous telecom R&D centre and has capabilities to undertake large scale state-of-the-art telecom technologies development programs.
6.	MEA	Ministry of External Affairs	The Ministry of External Affairs is responsible for India's international relations. Territorial divisions deal with bilateral political and economic work while functional divisions look after policy planning, multilateral organizations, regional groupings, legal matters, disarmament, protocol, consular, Indian Diaspora, press and publicity, administration and other aspects.
7.	NEST	New, Emerging and Strategic Technologies	The New, Emerging and Strategic Technologies is a nodal point to evolve and coordinate India's position on global governance norms, standards, architecture, and rules that are expected to come up for emerging technologies in a multilateral context, including at the

			UN and other mechanisms of regional cooperation.
8.	PM-STIAC	Prime Minister's Science, Technology and Innovation Advisory Council	It is an overarching council that facilitates the Principal Scientific Advisor's Office to assess the status in specific science and technology domains, comprehend challenges, formulate interventions, develop a futuristic roadmap and advise the Prime Minister accordingly.
9.	DoS	Department of Space	The Department of Space has the primary objective of promoting development and application of Space Science and Technology to assist in all-round development of the nation.
10.	ISRO	Indian Space Research Organisation	The Indian Space Research Organisation is the space agency of India. The organisation is involved in science, engineering and technology to harvest the benefits of outer space for India and the mankind. ISRO is a major constituent of the DOS
11.	DAE	Department of Atomic Energy	DAE is responsible for the entire spectrum of activities related to nuclear science and technology encompassing power generation, research, development, safety, security, safeguards, environmental protection, international collaborations and societal applications.
12.	DRDO	Defence Research and Development Organisation	DRDO is the R&D wing of Ministry of Defence, Govt of India, with a vision to empower India with cutting-edge defence technologies and a mission to achieve self-reliance in critical defence technologies and systems.
13.	NQM	National Quantum Mission	NQM is India's plan for scaling up scientific and industrial R&D and creating thriving ecosystem for quantum technology. It aims to accelerate quantum technology led economic growth and make India one of the leading nations in the development of quantum technologies.

14.	IIT	Indian Institute of Technology	The Indian Institute of Technology are central government funded technical institutes located across India.
15.	TIFR	Tata Institute of Fundamental Research	TIFR is a National Centre of the Government of India, under the umbrella of the DAE, as well as a deemed University awarding degrees for master's and doctoral programs. It conducts basic research in physics, chemistry, biology, mathematics, computer science and science education.
16.	Quantum EE	Quantum Entanglement Exchange	Quantum Entanglement Exchange program aims to facilitate the exchange of students, researchers, and professionals in the field of quantum technologies.
17.	QCAL	Quantum Computing Applications Lab	MEITY has collaborated with Amazon Web Services (AWS) to establish the QCAL. This lab will assist the scientific, academic, and developer communities in their R&D on quantum technologies.
18.	QuMaC	The Quantum Measurement and Control Laboratory	A quantum lab at TIFR which primarily investigates quantum phenomena in superconducting circuits,18 and has already made a 5-qubit quantum computer.
19.	QuIC	Quantum Information and Computing	A lab at the RRI, it is one of the first labs in India to manufacture and establish the usage of heralded and entangled photon sources towards various applications in quantum technologies. The lab has also collaborated with ISRO.
20.	RRI	Raman Research Institute	RRI is an autonomous research institute engaged in research in basic sciences.
21.	IISc	Indian Institute of Science	IISc is a research university for higher education in science, engineering, design, and management.

22.	CQuICC	Center for Quantum Information, Communication and Computing	Set up by IIT Madras, it has an objective of developing secure quantum communications, including quantum key delivery, quantum random number generation, quantum sensing and metrology, as well as quantum computing-related innovations.
23.	QuICST	Centre of Excellence in Quantum Information Computing Science & Technology	Set up by IIT Bombay for R&D in quantum simulation, computing, sensing and metrology, amongst others.
24.	IISER	Indian Institute of Science, Education and Research	Indian Institute of Science, Education and Research are centrally funded higher education institutes across India.
25.	HRI	Harish-Chandra Research Institute	It is an autonomous institute funded by DAE and conducts research on quantum communication, quantum cryptography, realisable quantum computing devices, especially ultra-cold gases and quantum optical systems, and foundations of quantum mechanics.
26.	NSCS	National Security Council Secretariat	The National Security Council Secretariat is a division under the MEA.
27.	CQuERE	Centre for Quantum Engineering, Research and Education	Established by TCG CREST, it carries out research in quantum computation and information, and train researchers and academia in India and internationally
28.	TCG CREST	The Chatterjee Group Centre for Research and Education in Science & Technology	TCG CREST is a private research institute.
29.	SQ-QuIC	SRMIST Qkrishi Centre of Excellence in Quantum Information and Computing	A quantum development centre set up by SRMIST and Qkrishi, a fintech company using quantum computing for the finance sector

30.	SRMIST	SRM Institute of Science and Technology	A premier institute for science and technology higher education
31.	EON	Energy Optimized Network	A patent filed by the quantum start-up Mphasis
32.	DoT	Department of Telecommunications	DoT oversees developmental policies for telecommunication services
33.	NIC	National Informatics Centre	NIC is under MEITY and has the objective to provide technology-driven solutions to Central and State Governments
34.	DIA 2023	Digital India Act, 2023	A proposed Act that seeks to enforce 'global standard cyber laws' which will have seven objectives, one of which is to 'address emerging technologies and risks'.
35.	DPDP Act 2023	Digital Personal Data Protection Act 2023	An Act to provide for the processing of digital personal data in a manner that recognises both the right of individuals to protect their personal data and the need to process such personal data for lawful purposes and for matters connected therewith or incidental thereto.
36.	NRF	National Research Foundation	The apex body in the country to provide strategic direction for research, innovation, and entrepreneurship in the fields of natural sciences including mathematics, engineering and technology, environmental and earth sciences, health and agriculture, and scientific and technological interfaces of humanities and social sciences.

37.	BIS	Bureau of Indian Standards	The national standards body of India, it develops standardization, marking, and quality certification of goods and services.
38.	SNAP	Standards National Action Plan	It will steer the national efforts for standards, certifications, and the specifications for future emerging technologies, amongst other sectors
39.	ISO	International Organization for Standardization	ISO is an independent, non-governmental international organization. It brings together experts to share knowledge and develop voluntary, consensus-based, market relevant International Standards that support innovation and provide solutions to global challenges.
40.	IEC	International Electrotechnical Commission	IEC is a global, not-for-profit membership organization, whose work underpins quality infrastructure and international trade in electrical and electronic goods.
41.	QED-C	Quantum Economic Development Consortium	QED-C is a consortium of international stakeholders that aims to enable and grow the quantum industry. Multiple agencies and a diverse set of industry, academic, and other stakeholders are working together to identify gaps in technology, standards, and workforce and to address those gaps through collaboration.
42.	ITU	International Telecommunication Union	ITU is the United Nations specialized agency for information and communication technologies
43.	IEEE	Institute of Electrical and Electronics Engineers	IEEE is the world's largest technical professional organization dedicated to advancing technology and has highly cited publications, conferences, technology standards, and professional and educational activities.

44.	TIFAC	Technology Information, Forecasting and Assessment Council	TIFAC India guides and catalyses national initiatives in Science and Technology. It publishes technology assessments and techno-market survey reports, technology roadmaps providing in-depth coverage of technology trends, status of technology in India, gap areas and technology linked based business opportunities.
45.	QSim	Quantum Computer Simulator Toolkit	QSim was launched by the Indian government to enable researchers and students to carryout research in quantum computing in a cost-effective manner
46.	PSA	Principal Scientific Advisor	The PSA's office aims to provide pragmatic and objective advice to the Prime Minister and the cabinet in matters of Science and Technology
47.	FTP	Foreign Trade Policy	FTP is the prime policy that lays down simple and transparent procedures which are easy to comply with and administer for efficient management of foreign trade in India
48.	SCOMET	Special Chemicals, Organisms, Materials, Equipment and Technologies	India's SCOMET list details Its dual-use items which must follow strict export and import regulations.
49.	FDI	Foreign Direct Investment	FDI is a category of cross-border investment in which an investor resident in one economy establishes a lasting interest in and a significant degree of influence over an enterprise resident in another economy
50.	iCET	Initiative on Critical and Emerging Technology	A bilateral initiative between India and US, which harbours cooperation between their governments, industry, and academia. It has several undertakings for quantum technology
51.	TCS	Tata Consulting Services	An India-based consultancy with outposts across the world

52.	TTC	Trade and Technology Council	TTC facilitates bilateral trade between European Union and India. They will cooperate on quantum and High-Performance Computing research and development projects
53.	DESI	Digitalisation, Education, Sustainability and Innovation initiative	DESI initiative aims to combine the strengths of India and Finland to create new business opportunities, drive innovation, and build a more sustainable future for all.
54.	SQA	Sydney Quantum Academy	SQA is supported by the New South Wales (NSW) government with a vision to build Australia's quantum economy, and is a partnership between four NSW universities. HCL Technologies (India) and SQA aim to bring together their capabilities to create education and development opportunities for students
55.	AICCTP	Australia-India Cyber and Critical Technology Partnership	A bilateral partnership between Australia and India to invest in cyber and critical tech collaborations and initiatives aims to support an open, free, rules-based Indo-Pacific region