India's Race to Quantum Supremacy

Quantum Revolution

A report covering How far has India come in quantum technology?, the Impact of Quantum Computing in India, it's Applications, New Opportunities, Potential Gaps, and Future Plans.

INDIA FUTURE FOUNDATION

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The Quantum Buzz

Quantum Computing applies quantum mechanics to computational problems to help businesses solve problems beyond the reach of conventional high-performance computers (HPCs) and solve existing problems significantly faster.

Quantum computing is based on entirely different physical processes than conventional computing. Quantum computers use quantum bits (qubits) as their most basic unit of information. Unlike conventional binary bits that are either 0 or 1, quantum bits can assume values of a combination—superposition—of 0 and 1. This characteristic of quantum physics enables new computing algorithms that can massively compress computation time. Quantum computing was first proposed in 1980. In the past few years, quantum computers demonstrated that they could outperform the most powerful supercomputers at specific tasks. For instance, Google claimed quantum supremacy in 2019 when it solved in seconds a problem that would have taken the world's most powerful supercomputer at the time thousands of years. While such achievements are extraordinary scientific breakthroughs, commercial uses of quantum computing are in their early days.

Quantum computing alters how data is stored and processed, drastically improving algorithm efficiency. Currently, quantum computing's primary focus is on optimization issues, which are difficulties in which the goal is to discover the optimal decision out of a large number of options. The quantum ecosystem is rapidly growing, allowing for the development of the "fifth generation of computers." While research continues, it inspires interesting advancements in traditional computing, spurring the traditional computing sector to emulate quantum techniques.

Classical Computers vs. Quantum Computers

01

Quantum computing typically reads binary values of 0 and 1, but it can retain considerably more complicated information, including negative values, than traditional computing.

02

Classical computing processes bits sequentially; in quantum computing, qubits are entangled such that altering the state of one qubit alters all other qubits, allowing quantum computers to converge on the correct answer very quickly. Due to this superposition property, quantum computers can do extraordinary calculations simultaneously.

03

Classical computing explicitly defines the desired outcomes, limiting the design of the algorithm; quantum computing enables simultaneous computations leading to several probabilistic outcomes, which increases confidence in the best answer.

State of the Quantum Market in India

- The quantum ecosystem in India is growing at an accelerated pace with support from government agencies (10-15) and active participation from academia (40-50), service providers (15-20), and the startup community (15-20).

- With increasing technology maturity, enterprise interest in quantum is beginning to rise.

- In 2019, quantum technology was identified as a "mission of national importance" by the government of India. Since then, there has been heavy public and defense investment in both core and applied research.

- India has made significant and differentiated strides in areas related to quantum communications.

- Indian technology players have identified quantum as a potential service opportunity for global and Indian clients and are developing proofs of concept (POC).

- The development of a local quantum workforce is a critical yet challenging requirement for the growth of this ecosystem.

"India's quantum computing ecosystem is expanding and is expected to do so at an accelerated pace over the next ten years."

The Quantum Industry's Technicalities

The Indian government has attempted to develop organizations and programs for quantum technology in order to keep the industry in check. Around 100 government-funded quantum and related technology, projects have reached various stages of development. Companies and the government have agreed to work together over the next five years to commercialize quantum solutions that are high-tech-ready. The Department of Science and Technology (DST) has pioneered the Quantum Information Science and Technology (QuST) program to lay the groundwork with the help of infrastructure and people resources.

- **The QuST:** QuST will bring together and fund academic research groups to create quantum products in areas where they are most needed. It will also help to speed up initiatives that have been put on hold. The development of 8 qubit quantum computers, communication (fiber and free space), and cryptography, for example, will become increasingly significant. Meanwhile, advances in quantum algorithms, advanced mathematical quantum approaches, and quantum information system theory will continue to be made.

- **The NMQTA:** The National Mission on Quantum Technologies and Applications (NMQTA) is the next investment initiative in line, with a greater budget and ambitious goals. Quantum computers with highly secure quantum communication, quantum key distribution (QKD), quantum clocks, sensors, imaging devices, and startup collaboration are among the goals of the NMQTA. It will also release smaller-scale gadgets such as quantum simulators and sensors. QKD systems will be developed into field-deployable products in the meantime. Using QKD in satellites and fibers will also make long-distance quantum communication a reality. The hype around 5G in India will be crucial in bringing the quantum internet to life.

The Fight for Quantum Dominance on a Global Scale

Quantum technology is still in its infancy, and it will be a few years before it can be put into practice. The Boston Consulting Group (BCG) forecasts that in the next three to five years, it will add $5 billion to $10 billion in value. According to the group, this sum will reach the US $450 billion in the next fifteen years. Given the extent and potential of this technology, governments, technological companies, and academic institutions have been devoting resources to establishing quantum supremacy or quantum advantage. This historic achievement was announced by Chinese experts in June 2021. Google celebrated this achievement in October of this year. India, Canada, Germany, and France have each pledged more than a billion dollars to the growth of the country.

By creating the National Mission for Quantum Technology and Applications (NM-QTA) in 2020, India formally entered the race for quantum computing. To keep up with China and the United States, India must identify and address a few major policy gaps. This will help India compete in the global quantum race, but it will also usher in a new era of technology policymaking in the country.

Potential Gaps in India's Approach

- **Stakeholder Network : India's quantum ecosystem is haphazardly constructed. While India has invested billions in quantum computing, there is no comprehensive multi-stakeholder network in place. It's unclear whether India would focus on quantum applications shortly, long-term uses, or both. India's quantum initiatives should focus on translating research into practical uses.**

- **Lack of Standards : Next, there are no well-defined benchmarks for evaluating India's quantum initiatives. Obtaining quantum supremacy alone will not guarantee that India's national interests are protected.**

- Lack of Researchers : In the field of quantum computing, India has a modest talent pool in terms of capacity and trained professionals. In the country's quantum computing field, there are now only a few hundred researchers, industry experts, professors, and entrepreneurs. India trails considerably behind China and the United States.

"A few private companies and startups have started to develop these critical quantum components, but most hardware is still imported."

Quantum application development will also necessitate the convergence of several technology domains, including quantum information theory, quantum communication, storage, quantum computation, and quantum hardware development. To realize its quantum potential, India will need to boost its computational power and work on manufacturing more complicated semiconductor processors. Research is being conducted in silos, and knowledge exchange is unstructured. There is a lack of a uniform platform for all quantum research and development in the country.

- Hardware Manufacturing : India has not been able to build its hardware manufacturing capabilities over the last many decades. India will require superconducting materials, physical qubits, a data plane, chips, processors, and fabrication laboratories to construct a quantum computer at home. There isn't enough impetus here. Although a few private enterprises and startups have begun to develop these key quantum components, the vast majority of the hardware remains imported.

- Research Facilities : Finally, the majority of quantum-related research and development takes place on university campuses. While universities can deliver well-researched prototypes, industry collaboration is required to turn them into scalable applications.

National Gap Areas

Although India is well-positioned to benefit from the next wave of quantum technology advancements, India's present expertise and facilities pale in comparison to global developments. Even in carefully selected domains, expanding the realm of quantum technologies from this point is a substantial problem.

i. Lack Of Resources At The Undergraduate And Graduate Level:

A significant impediment in India is a dearth of quantum computer resources, which would allow seven undergraduate and graduate students to enter the area. Quantum computing is primarily taught at the graduate level in the West, and students must have a strong background in higher mathematics and quantum physics. Students with a background in physics and computer science can pursue quantum computing; however, there are just a few institutes in India that teach quantum computing, the most notable of which being the Raman Research Institute, HRI Allahabad, and IISc, which has a quantum computing research center.

ii. Increase University Level Adoption:

If India wants to develop a quantum-ready workforce, increase R&D manpower, and compete on a global scale with China, the United States, and Canada, it must develop quantum science and engineering as separate disciplines at the graduate level. This will need to be accompanied by the addition of new academics and a deeper level of engagement with industry players. To accelerate quantum research and development, more money would need to be invested in the establishment of QT research centers through public-private partnerships. In addition, the government would have to take the lead in raising knowledge of quantum science in secondary schools.

iii. Build Technical Infrastructure To Advance Quantum Technologies:

To progress quantum technology development in India, the government and stakeholders will need to determine the infrastructure required and training and engagement opportunities. Aside from assessing the quantum landscape from a technical and policy standpoint, India will need to sustain its technical infrastructure by establishing quantum technology innovation labs.

iv. Government Support

Given venture capital investment in quantum startups continues to be slow, government support is necessary to scale startups.
Key challenges faced by Indian startups while raising funds for product development and scaling

1. Undervaluation during funding

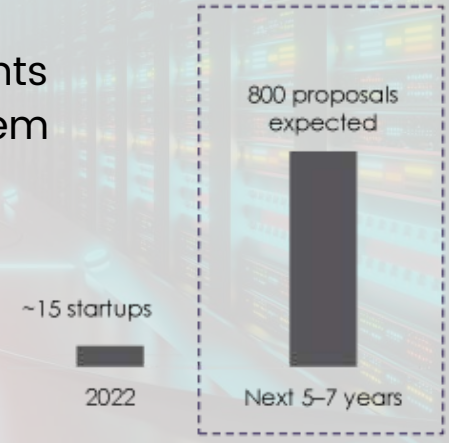
- Company valuation is not based on current progress but on when it was incorporated.
- Given most quantum startups do not have a long history, this leads to inadequate valuation.

2. Short-term horizon of most venture capital

- Typically, seed money and venture capital is provided only for less than five years.
- Given the complexity of quantum product development and the pace of fundamental research breakthroughs, most startups require a significantly longer runway of funding.

Consequently, government grants are critical to nurture this ecosystem for the next 5–7 years

Grant-driven expansion of the quantum startup ecosystem in India



India's Way Ahead

India has long been a major technology importer.

India purchased $10.4 billion in hardware and software in 2020, while just $0.3 billion in technology was exported. India must rethink and revise its technology policy objectives, frameworks, and deliverables in order to transition from an importer to an exporter of quantum technology.

Metrics

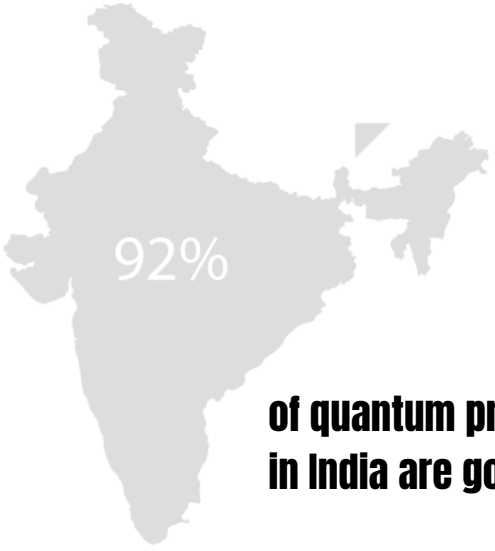
India should develop metrics to analyze the success of its strategy and action plan to overcome policy gaps. The Department of Science and Technology announced the Quantum-Enabled Science and Technology (QuEST) program, which will invest INR 80 crores in infrastructure and research. While the plan appears detailed and visionary on paper, it will require the development of a periodic feedback system to track the progress of its goals. The number of patents filed could be one such indicator. The quantum mission's monitoring and evaluation must be prioritized.

Entrepreneurship

Entrepreneurship, innovation, university courses at all levels, scholarships, fellowships, training programs, and consulting in quantum technology will all be important in building a knowledge ecosystem and closing the talent gap. As a result, India will develop a dedicated quantum community capable of cooperating with researchers and industry professionals worldwide. Scholarship and professional skills in several parts of quantum technology development will also benefit from such initiatives.

Investments

India must also strengthen its investor environment, which will aid in the production of quantum computer hardware components and applications. With the rise in demand for semiconductor chips brought on by these computers, India has to boost its semiconductor sector at the same time. The government has pledged significant financial assistance to the industry to stimulate the design and development of these chips in India. The government can also help them with production-linked incentive schemes and programs like the Scheme for Promotion of Manufacturing of Electronic Components and Semiconductors, which help market players like Intel and AMD.



of quantum projects in India are government sponsored

The remaining 8% of initiatives are either run by the startup community or by independent, nonprofit organizations such as Quantum Ecosystems and Technology Council of India and Quantum Research and Centre of Excellence

While India's quantum technology plan appears to be ideal on paper, key agencies should ensure that it recognizes and addresses these policy and implementation deficiencies as soon as possible for India to emerge as a global leader in the quantum technology area.

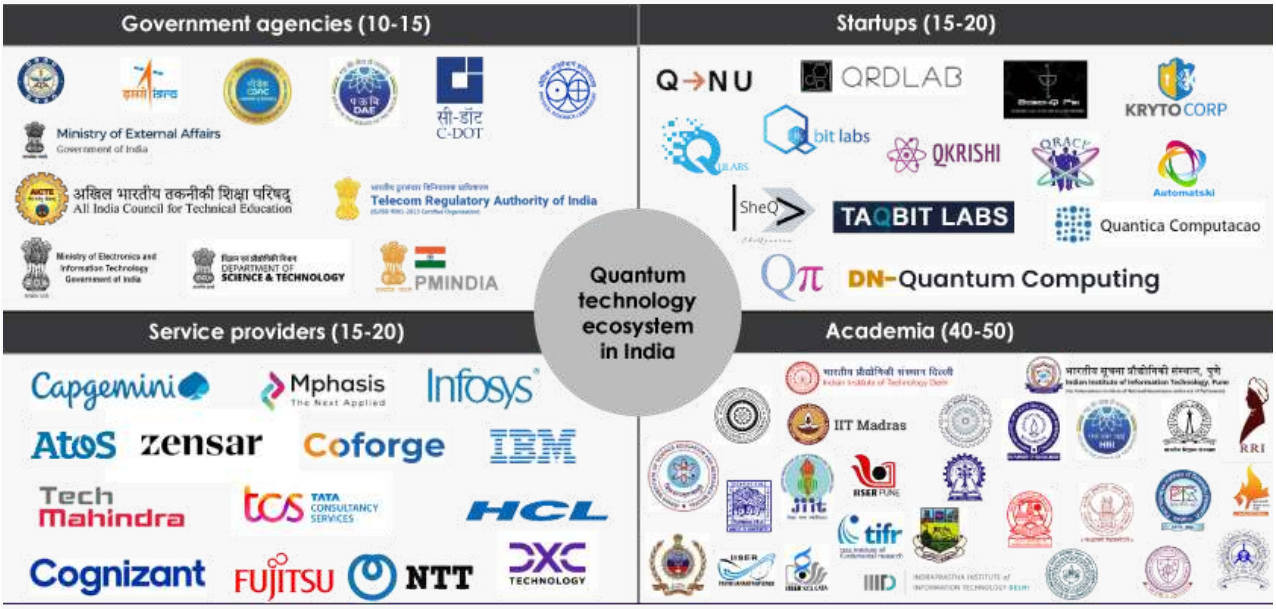
Sources: Avasant Research, expert consultations

Key Initiatives by the Government

India saw many key initiatives in the quantum tech industry. Let us look at the most critical steps taken by the government.

The Indian Army established a quantum computing facility and an AI center at a military engineering institute in Mhow, Madhya Pradesh, in December 2021. The National Security Council Secretariat also supports it (NSCS). In addition, after unveiling a QKD solution in October 2021, the Centre for Development of Telematics (C-DOT) opened a quantum communication lab. An ordinary optical fiber can support a distance of more than 100 kilometers.

The Defence Institute of Advanced Technology (DIAT) and the Centre for Development of Advanced Computing (C-DAC) decided to work together on quantum computers in July 2021. Meanwhile, the DST and roughly 13 research groups from IISER Pune created the I-HUB Quantum Technology Foundation (I-HUB QTF) in March 2021 to advance quantum technology development. In January 2021, the Ministry of Electronics and Information Technology (MeitY) collaborated with AWS to build a Quantum Computing Applications Lab to promote quantum computing-led research and development.



Sources: Avasant Research
Note: Indicative list of examples. Numbers in parenthesis indicate the number of entities currently active in the Indian quantum ecosystem.

The QuST Program

The QuST program intends to coordinate and fund academic and research efforts to develop quantum products in sectors where technology readiness is already strong and accelerate the development of quantum technologies that are now at a low readiness level.

"More than 51 projects are funded under the QuST program. Current disbursement is only 50% of planned funds."

Expected deliverables-

- Development and demonstration of 8 qubit quantum computers, communication (fiber and free space), and cryptography.
- Development of application-specific quantum algorithms.
- Advanced mathematical quantum techniques, algorithms, and the theory of quantum information systems are being developed.
- Generate about 100 PhDs in quantum.
- Train 2,000 undergraduates, postgraduates, and students in advanced algorithm and application development using quantum systems.

Key investment themes

- Quantum information and meteorology
- Quantum applications and materials
- Quantum communications

>51 projects are funded under the QuST program. Current disbursement is only 50% of planned funds.

Expected Deliverables

Develop an indigenous quantum computer

- Development and demonstration of 8 qubit quantum computers, communication (fiber and free space), and cryptography.
- Development of application-specific quantum algorithms
- Development of advanced mathematical quantum techniques, algorithms, and theory of quantum information systems

Human resource development

- Generate about 100 PhDs in quantum
- Train 2,000 undergraduates, postgraduates, and students in advanced algorithm and application development using quantum systems

The NMQTA (National Mission on Quantum Technology & Applications) Program

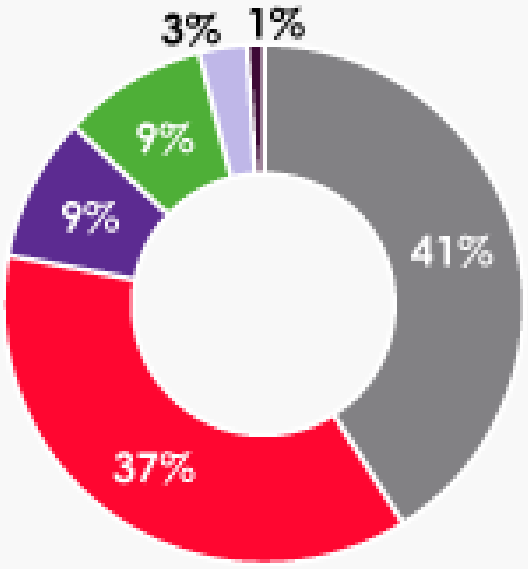
Aims of NMQTA

The specific operational goals of the NM-QTA are to:

- Evolve a long-term strategy (10 years) with short-term (5years) targets and associated calculated investments. An integrated approach and convergence model for academia, industry, and government organizations to jointly accelerate the growth of the quantum technology ecosystem.
- Develop and demonstrate Quantum Computers, Quantum Communication, and Produce quantum algorithms and new applications.
- Develop conventional technology and intellectual property needed to support and enable quantum technology
- Engineer, industrialize and connect to economic growth and jobs creation, and maintain a competitive advantage as a global supplier of quantum devices, components, systems, and expertise while playing a leading role in engaging globally in the development of quantum technologies.
- Support the free flow of people, innovation, and ideas between academic, industrial, and government organizations
- Nurture in the development of a world-class industrial quantum technology workforce.
- Continue the fundamental research needed to support these NM-QTA goals and those that arise from the capabilities of quantum technologies.

Expected distribution of USD 1B funding under NMQTA

- Center for Development of Quantum Technology (C-DOQ)
- Technology development (theory and experiments)
- Human resource development
- Innovation and startup ecosystem
- International collaborations
- Mission management unit



Source: Technology Information Forecasting and Assessment Council (TIFAC)

Develop an indigenous quantum computer

- Build a quantum computer with ~ 50 qubits in a timeframe of five years.
- It will be developed using at least one of the technological approaches such as trapped-ion or superconducting.

Commercialize quantum solutions with high readiness

- Launching smaller scale devices, such as quantum simulators and sensors, using most of the other technological approaches is also expected.
- Translation of QKD systems into field-deployable products.

Establish long-distance quantum communication

- Achieve long-distance quantum communication by implementing QKD across hundreds of kilometers through satellites and fibers.
- It will be a significant step in the development of the quantum internet.

Objectives of NMQTA

- To promote and foster R&D in Quantum Technologies and related areas like quantum computing, quantum cryptography, quantum communication, quantum metrology, sensing, quantum-enhanced imaging, etc.
- To develop and demonstrate quantum computers, quantum communication (Fiber and Free Space), and Quantum key distribution.
- To develop technologies and prototypes and demonstrate associated applications pertaining to national priorities.
- To develop infrastructure pertaining to the development of these technologies.
- To enhance a high-end research base, Human Resource Development (HRD) in these emerging areas.
- To establish and strengthen the international collaborative research for cross-fertilization of ideas.
- To enhance core competencies, capacity building, and training to nurture innovation and the Startup ecosystem.

Centre for Development of Quantum Technology (C-DOQ)

The Centre for Quantum Technology Development (C-DOQ) emerges as a critical strategic asset used to manage complicated change activities.

A center of excellence is a team mandated to focus on a particular field of research in academic institutions; such an entity may bring together faculty members from several disciplines and provide shared facilities.

All significant actions will be carried out through C-DOQ, which is at the heart of the NM-QT Mission's implementation. It will be divided into five sections, each focusing on a distinct aspect of technology, translation, applications, operation, and commercialization.

It would establish connections and collaborate with a network of research institutes and laboratories in India and overseas.

The key specialisms of the center are:

- Components and technology: development and assembly of quantum devices or industry-ready clocks, measurement devices, and sensors.
- Calibration and services: building measuring stations that can define and calibrate the above components and technologies.
- User platforms (—user facilities‖): making fiber-optic networks and technology platforms available for prototype development and small batch production.
- Business incubators, training, public relations, support for technology transfer: providing and operating an incubator laboratory for transferring quantum technologies to applications; training centers for engineers.
- Publicity and media coverage: The quantum technologies community must pursue a consistent and inspiring message with media organizations to ensure public awareness and understanding develops in parallel with the technology. The quantum technologies program and the quantum hubs will work with the media to grow awareness of the program worldwide.

India and Finland to Establish a Virtual Centre of Excellence (CoE) in Quantum Computing.

India and Finland addressed potential areas of quantum computing collaboration for the virtual Centre of Excellence (CoE). Delegates from India and Finland reviewed a path for the joint virtual Centre of Excellence (CoE) that is expected to be established during the meeting.

"The two countries are seeking to acquire academic and industry partners who can help advance quantum science and technology for the good of humans in particular and the planet in general," Dr. S Chandrasekhar, Secretary Department of Science and Technology (DST), said during the meeting. We are dedicated to achieving global superiority in this industry to develop the most advanced technology in the shortest period possible."

He also emphasized the importance of identifying the strengths and shortcomings of both countries in this area and working together to develop a strategy to address the flaws by forming a core group to lead the endeavor.

On the other hand, Petri Peltonen, Under-Secretary of State, Ministry of Economic Affairs and Employment, Finland, emphasized the need to combine the best of Finland with the best of India, leveraging both nations' scientific ecosystems strong IT communities to encourage spin-offs.

TCG Plans to Develop India's First Private Sector Quantum Computer

TCG Group has announced that it will build India's first private sector quantum computer in Kolkata, ushering in a new era in science.

TCG, directed by Purnendu Chatterjee, has recently revealed that it is seeking university status for TCG CREST, an established research center where Ph.D. scientists work on cutting-edge technology.

Chatterjee unveiled the projects at the state government's sixth Bengal Global Business Summit. He didn't give an exact figure for quantum computing and research investment but indicated it might be in the thousands of crores of rupees.

According to a corporate spokesman, the country's defense department has established a quantum computing facility.

Quantum computing, neurosciences, cryptology, data-driven intelligence, and sustainable energy are all areas where CREST is engaged, he noted.

According to Chatterjee, the research is being guided by internationally recognized scientists who have joined the program from institutions and universities known for their global research leadership.

NSM: Strengthening India's Supercomputing

By developing the expertise to design and construct supercomputers in India, the mission aims to provide the country with supercomputing infrastructure to satisfy the rising computational demands of universities, researchers, MSMEs, and startups.

The National Super Computing Mission is a first-of-its-kind effort to boost the country's computing power, and it is led by the Ministry of Electronics and Information Technology (MeitY) and the Department of Science and Technology (DST), with the Centre for Development of Advanced Computing (C-DAC) in Pune and the Indian Institute of Science (IISc) in Bengaluru as implementation partners.

About Our Company

A Brief Story About The Company

India Future Foundation, registered by the name “Incalculable Cyber Awareness and Research Foundation” - (ICARF) is a Not-for-Profit Think Tank leading initiatives to drive change on Digital /Internet Policies with an aim to foster & build Digital Ecosystems that guarantee Freedom of Expression, Trust, and Safety for users. India Future Foundation works towards creating cyber awareness about emerging online threats to the online safety of women and children against online sexual abuse & exploitation, leading the action from the front to create impact by working with the Government, Enterprises, and Startups.

Our areas of work include advocacy, cyber security policy, and governance with an aim to make the Indian Digital Eco-system safe from threats and protect India’s National Critical Information Infrastructure through policy reccomendations, while also working towards capacity development through the various awareness programs we run throughout the country.

India Future Foundation

Freedom of Expression, Trust and Safety on Internet

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