QUANTUM COMPUTING

TRANSFORMING TECHNOLOGY

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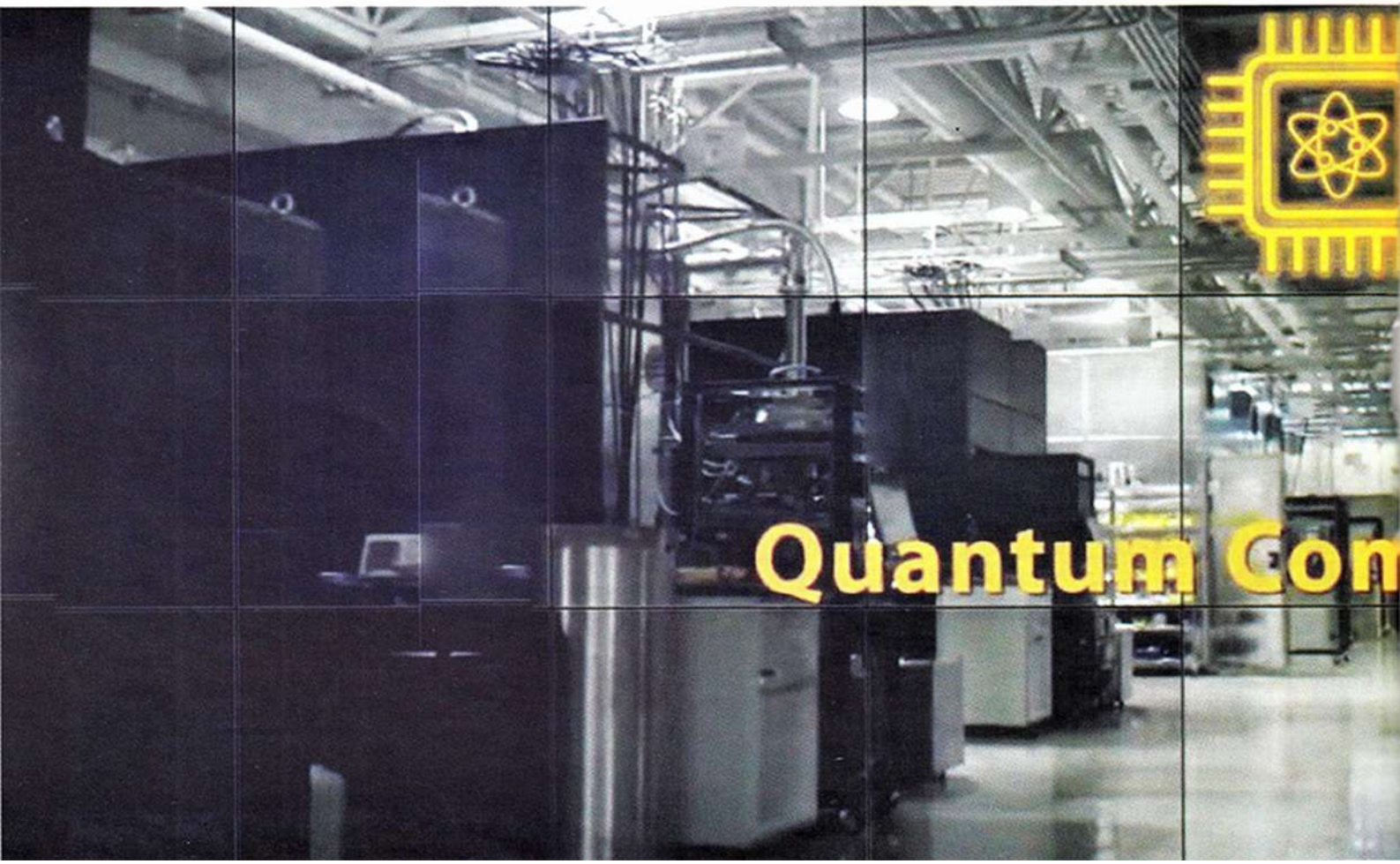
Quantum computing differs from traditional computing, which uses 'bits'—binary digits of 0s and 1s — to represent information. However, quantum computing uses quantum bits, or 'qubits', which can exist in multiple states simultaneously, instead of just two states (i.e., 0 and 1). This property of qubits, known as 'superposition' allows quantum computers to perform many computational calculations orders of magnitude faster than classical computing. Further, quantum computing also borrows inspiration from another property of quantum mechanics called entanglement, wherein two qubits could be connected in such a way that the state of one qubit intrinsically affects the state of the other qubit. As quantum computing moves steadily towards real-world applications, it continues to be a thriving area for interdisciplinary research and booming scholarly outputs, as well as new fundamental discoveries in physics. In 2012, Serge Haroche and David Wineland were awarded the Nobel Prize in Physics for their ground-breaking experimental methods that enable the measurement and manipulation of individual quantum systems. Their work has profound implications for quantum information and quantum computing.

Nations and industries are slowly and steadily gearing up to leverage the quantum computing wave through strategic collaborations and investments in research and innovation. This wave may transform the entire technology ecosystem; indeed, one that may fundamentally transform society, culture, and the economy.

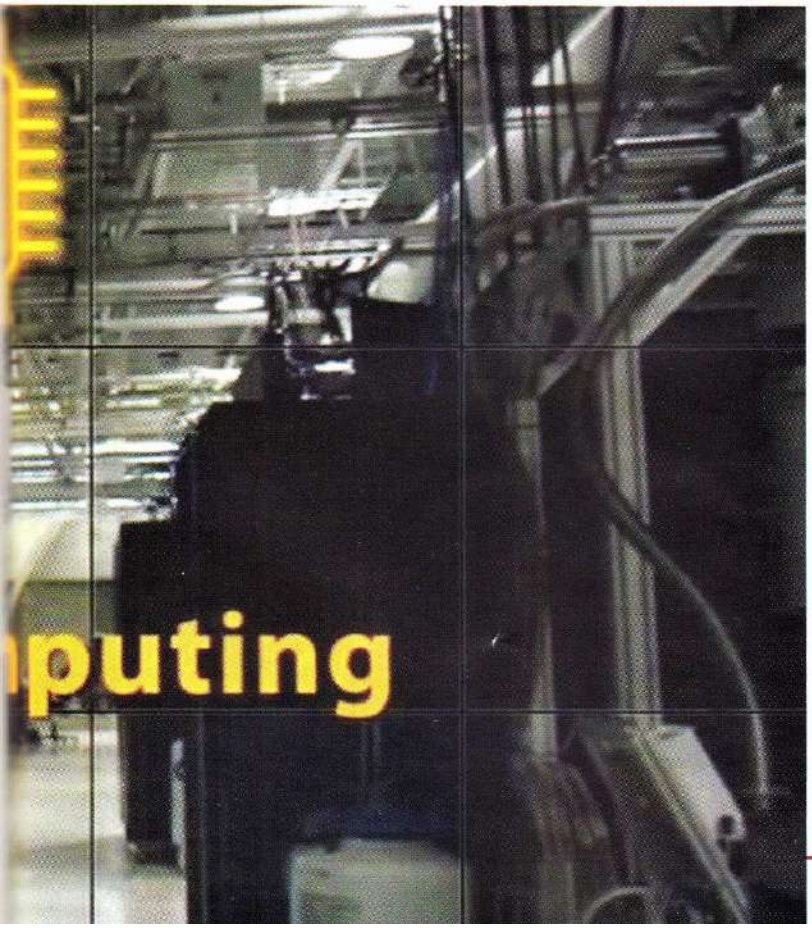


Quantum computing is an advanced area where research and development are still at a nascent stage. However, this presents an opportunity for India to establish well-funded research Centres of Excellence in the leading technological institutions. Long-term schemes of the Department of Science and Technology could possibly be introduced whereby strategic infrastructure and manpower training projects can be funded in the established technology engineering institutions. This would need to cover both hardware and software to further develop a homegrown quantum technology industry.

Quantum computing is still a relatively young domain, and while practical quantum computers are now commercially available, they are currently limited to performing very specific types of calculations. However, researchers believe that quantum computers have the potential to revolutionise fields such as data sciences, artificial intelligence, and decision sciences. We attempt to deliberate on the following important elements of quantum computing evolution:

1. How would the evolution of quantum computing impact the nation and society?
2. How can policy interventions be planned now to ride the wave of quantum computing as the field matures?

The subsequent sections would attempt to address these questions stage-wise. First, we discuss the impact of quantum computing; then, we discuss the implications for policymakers, and finally, we conclude the article.

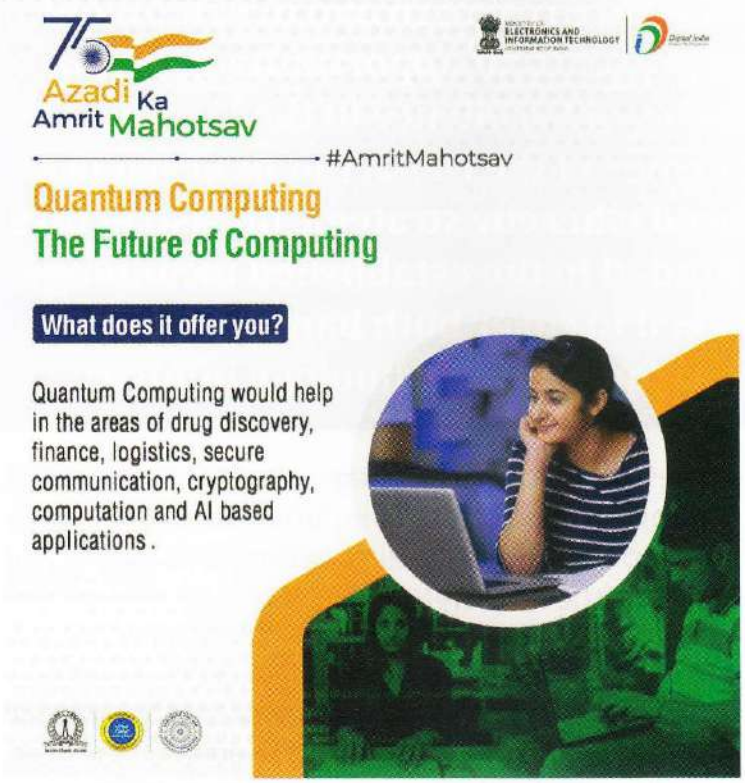


Impact of Quantum Computing

Given India's growing capabilities in the space of information technology (IT) and IT-enabled services, including technology consulting capabilities, we foresee that the future of quantum computing is going to drastically revolutionise the skill needs and capabilities of the emerging skill force, which is gradually gearing up in the space of data science, artificial intelligence, machine learning, and decision sciences. Here are a few areas where the impact of quantum computing is likely to be felt:

Faster data analysis in industrial data science applications: Quantum computers can perform certain types of calculations significantly faster than classical computing logic. As these types of computations increase in scope and scale, this could enable faster data analysis for business problems in the era of big data, particularly for large datasets created with high velocity.

Improved machine learning outcomes: Machine learning algorithms are increasingly being used for predictive capabilities and enhanced data-driven decision-making. In the era of cognitive computing, these algorithms may focus on complex data types like images and videos for solving business and social problems through areas like computer vision. Quantum computers could potentially improve machine learning by enabling more efficient optimisation of these algorithms so that computer vision capabilities become more efficient, accurate, and fast. Further, in applications of generative artificial intelligence, quantum computing could potentially have better recommendations since it



would be possible to create architectures that analyse real-time additions to the web of knowledge in the digital world to create advice. The outcome of these capabilities would translate to the development of areas like driverless cars, automated management of smart city infrastructure, and digital public services.

Improved optimisation for complex problems: Many analytics problems involve finding the optimal solution to a complex problem. Quantum computers can potentially solve these problems much faster than classical computers, enabling more efficient optimisation of complex systems. This may create faster optimisation of very large-scale problems involving complex network structures, computational biological sciences, and physical sciences. Local optimisation can be avoided, and quantum computing may enable the achievement of global optimal solutions in problems that typically demonstrate high multi-dimensional computational complexity, or indeed NP-hard problems.

Improved industrialisation: Realisation of industrial maturity levels such as Industry 4.0 and beyond, through platforms like digital twins would be enabled through quantum computing. The Distributed computing networks, federated learning, 'Internet of Everything', blockchain, and related technologies can be envisioned to become more efficient in terms of achieving their desired objectives computationally as well as in terms of quality of outcome.

Improved process efficiencies in digital transformation: Quantum computing may result in faster process automation by analysing real-time data generated in the organisation processes. This may make the organisations nimbler to change in the information ecosystems within which they operate. Further, these platforms may enable organisations to connect with multiple stakeholders through open network architectures to make information flow and processing seamless and real-time.

Implications for practice and policy

The possibilities that quantum computing can open up are immense, and there are serious deliberations that are needed from a public policy viewpoint. We list some of these deliberations below:

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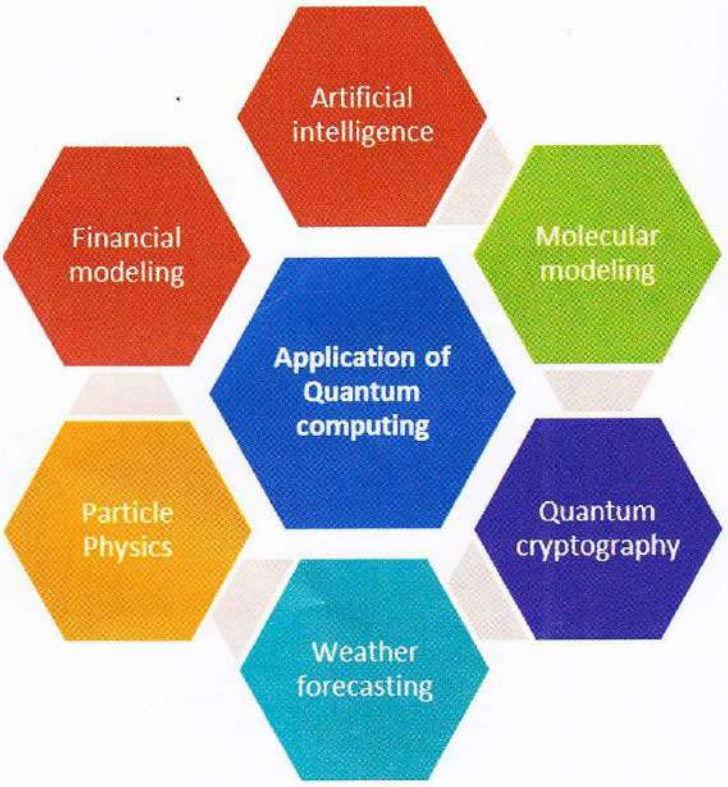
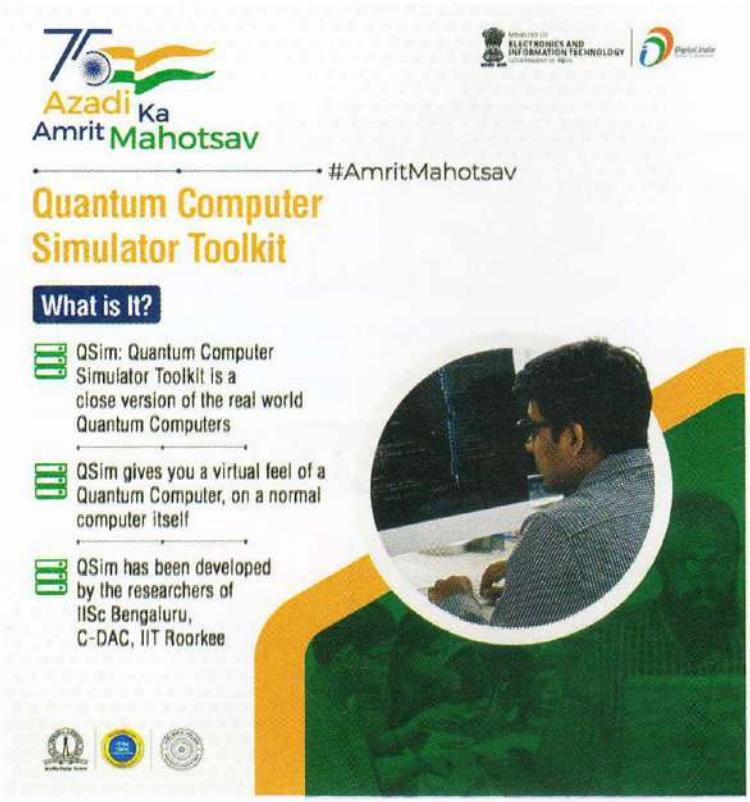
Furthermore, quantum computing also needs clear and sustained policy and governance since it





deals with new levels of data and computation. The legal frameworks surrounding data management, data sharing, data privacy, information assurance, algorithmic governance, and transparency need to evolve. This is where sponsored projects need to be created to form a knowledge repository surrounding how data governance and policy frameworks should evolve. Similarly, frameworks surrounding security, transparency, accountability, fairness, and ethical use of quantum computing systems also need to evolve. This is where social scientists would be needed to explore and develop inputs for policy making, and co-creating these outcomes from the start of the interventions and projects. Frameworks surrounding information governance, information access, and information dissemination may need to be revisited given these emerging computational capabilities.

Skill areas of data science, decision science, and machine learning are going to be intensely impacted in the near future by quantum computing. This is where policymaking at the national level needs to create consolidated efforts towards the future talent and skill development of the large young population that India boasts of, to make them future- ready. So, the skills of the existing workforce need to be geared towards better understanding data science and decision science, so that they can take advantage of the wider quantum computing domain over the coming years. Manpower skilling is an important component for the employability of the future workforce of India, and this may require policy intervention since most private organisations focus on exploiting immediate skill availability and project needs by compromising future skilling needs. However, these employees who do not develop future skills suddenly become irrelevant when the technology ecosystems evolve, resulting in job losses.

Realisation of digital healthcare and biomedical research would be strongly facilitated using quantum computing. Quantum computing is a global field, and collaboration is crucial for making progress. International funding agencies could develop joint project funding schemes whereby collaborations can be fostered to enable faster development in this space. Mobility grants need to be augmented by infrastructure and manpower hiring grants for these projects to be really impactful.

Startups can generate huge opportunities that disperse the burden of economic welfare and employment from metro cities. Startups focusing on quantum computing can be encouraged using government support through organisations like the Technology Development Board, where grants can be given to startup ventures in non-metropolitan cities in the space of quantum computing product development. These initiatives can also facilitate the full realisation of national missions such as Make in India over the coming years.

Conclusion

The quantum computing domain is an area that the government must focus on because it will be heavily dependent on exploiting information assets within and outside the organisations in the long-term. There is a significant opportunity for India; for moving towards that direction as it is envisioned that strategic investments in research, development, and training mechanisms should be created. This may enable improved capability for leveraging and exploiting this domain for the benefit of citizens and the nation going forward.

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