Quantum Technologies in the Defence Sector: Assessing Strategic Implications for India's Future Warfare

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Abstract: The global security architecture and the Indian defence system have been revolutionised due to the advancement of technology, and because of this, the architecture is poised at the juncture of the second Quantum revolution, which is not only a drastic progress but also signifies how far we have come since the time of independence. While discussing the second Quantum revolution we cannot negate the fact that the first quantum revolution was quite significant in nature as it ruled throughout the 20th century and also managed to harness the statistical properties and elements of the quantum mechanics to develop foundational technologies such as the transistor, the laser, and the atomic clock, the contemporary era is defined by the transition to Quantum Revolution 2.0.

This New Era is considered as one of the most progressive eras as it is distinguished by the capacity to control individual quantum systems, such as atoms, ions, photons, and electrons, in order to take use of the "strange" principles of quantum physics, such as tunneling, entanglement, and superposition, at the boundaries of known physical reality.

This paper shall focus upon the analytical research of quantum technology and how it has shaped the defence sector globally. This paper also highlights the multiple utility of this technology and its incorporation in India. In the end it proposes a study of its good and bad sides by highlighting the recent setbacks posed by them.

Keywords: security, defence, quantum, atomic, technology

I. INTRODUCTION

The deployment of quantum technology in the defence industry makes one such promise. This promises a new way of dealing with strategic imbalance, where decades of spending on stealth would become futile; and even underwater environments would be rendered transparent. Most importantly, cryptography and information security will become irrelevant, with everything exposed to attacks. Given how peer competitors like the Chinese PLA are working towards achieving "quantum supremacy" through their own modernisation agenda, it is imperative that India assesses these emerging technologies with the perspective of strategic deterrence and informational autonomy. For that, the implementation of the National Quantum Mission (NQM), which got approval from the Union Cabinet in April 2023 with an allocation of ₹6,003.65 crore, can be considered

a starting point. The development of quantum technology is not only a scientific evolution brought to the defence sector but it also is a fundamental change towards the matrix situated in the volatile geopolitical atmosphere.
The military utility of this Quantum technology and its incorporation in the defence sector promises us the world free of any kind of security and threat issues.
This document offers a comprehensive evaluation of the state-of-the-art quantum technologies in the defence industry along with implications for India in future warfare and associated strategies.
The primary **research problem** identified in this analysis is the burgeoning **"quantum gap" between classical military architectures and emerging quantum capabilities**. Traditional pillars of national security, mathematical encryption, acoustic-based anti-submarine warfare, and radar-based stealth, are facing obsolescence due to the development of Shor's algorithm, quantum magnetometers, and quantum illumination. For India, this disruption is not merely technical but existential, as it threatens to undermine the survivability of the sea-based nuclear deterrent and the integrity of secure command-and-control networks.

The major **research problem** highlighted through this study includes the growing **"quantum gap" between classical military doctrines and quantum technologies**. Classical military doctrines such as the use of mathematics for encryption, sonar technology in anti-submarine warfare, and stealth technology through radar technology will soon become obsolete owing to developments like Shor's algorithm, quantum magnetometers, and quantum illumination. For India, the issue goes beyond mere technological disruption as the survivability of its nuclear-powered submarines and communications network is under threat.

Therefore, the **research question** that forms the basis of this research paper is as follows: How can India design a quantum ecosystem that can help it achieve strategic deterrence and information freedom within the Indo-Pacific and Himalayas? In addressing the issue, the analysis employs a well-defined conceptual framework derived from the quantum warfare taxonomy proposed by Michal Krelina in the evaluation of the military applications of quantum technologies. The analysis evaluates quantum technologies on the basis of sensing, communication, computing, and materials.
Conceptualization of quantum technologies in the context of military operations necessitates a departure from science to the "Quantum Warfare Framework." This framework posits that quantum technologies do not necessarily introduce fundamentally new weapon types, as nuclear or laser technologies did, but rather serve as "capability sharpeners" that exponentially increase the precision and efficiency of existing military functions. The QWF organizes these applications into four distinct but interdependent domains, each contributing to the modernization of the Indian Armed Forces.
As with any emerging technology such as semiconductors, AI, nanotechnology, spatial computing, synthetic biology, and nuclear fission, quantum brings with it interrelated ethical, legal, socio-economic,
and policy implications (Quantum ELSPI) and concerns. One such concern is that of technological justice: how we can ensure that all of humankind can reap the benefits of innovating with and using these promising technologies in an equitable manner, warranting safe, responsible access to them?
Like any new technology like semiconductors, AI, nanotechnology, spatial computing, synthetic biology, and nuclear fission, quantum comes with its associated ethics, law, socio-economics, and policies (Quantum ELSPI), among others. Technological justice, i.e., how to ensure that humanity at large can benefit equally from these innovations and technologies through innovation and usage, may be another concern. The issue of dual use of quantum technologies, i.e., whether quantum technologies could be used for civilian and military applications, is also important to consider. While dual use itself is not inherently undesirable, it would be

desirable to avoid military applications of quantum technologies by competitors, to prevent terrorist attacks through illegal applications of quantum technologies, and to prevent quantum-AI hybrids from changing warfare forever. In developing policies around quantum technologies, we should draw lessons from policies regulating nuclear fusion and nuclear fission technologies. Their continued development and use are based on the potential for nuclear isotopes to have medical applications and the potential for nuclear fission technologies to provide enough power for an entire city. We have not done much about addressing the destructive powers of nuclear weapons.

But one might be able to use lessons from the missteps in policies, and leverage successes in policy, in dealing with other disruptive technologies and AI, which is an area in which one sees every day the extent to which governments need to collaborate with corporations and academic institutions in taking positive steps toward countering disinformation with verifiable factual information and preventing techno-authoritarianism, discrimination against minorities, and winner-take-all tendencies.

These issues necessitate the creation of systems of governance through which norm-setting and regulation become consistent with a liberal democratic conception of a free world, founded on the principles of civil liberties and human rights and the rule of law. Quantum technology and artificial intelligence have mind-boggling capabilities that cannot even be imagined for both immense benefit and immense danger. Hence the drive to innovate cannot be the only driving factor behind their planning, development, and deployment. In order to ensure that these miracles do not pose any threats out of the reach of human imagination, there needs to be a value-system in place when it comes to their financing, development and deployment, with an emphasis on civil society’s most pressing needs, including economic stability.

The theoretical underpinning of this framework is the "Quantum Power Parity" (QPP) model. Unlike nuclear parity, which is verifiable through treaty-based inspections and headcounts, QPP is inherently unstable due to the dual-use nature of the technology and the difficulty of verifying computational capability or sensor sensitivity. This instability necessitates a proactive stance for India, as falling behind in the quantum race could lead to a strategic vacuum where an adversary possesses both superior sensing and unbreakable security.

II. Significance

Quantum technology is set to revolutionize modern warfare through the development of communication, computing, sensing, and encryption capabilities. Their use within the defense industry will have a profound impact on issues of national security, strategic advantage, and technological sovereignty.

Defense Advancement Through Quantum Technology: Quantum computers, quantum communications, and quantum sensors have great potential in advancing intelligence gathering, secure communication, and decision-making during military campaigns.

National Security Through Quantum Encryption: Quantum cryptography provides unparalleled security when it comes to information, offering an edge against cyber warfare and espionage.

Global Power Dynamics: Quantum technology will change the existing global balance of power, thereby making it important for India to be competitive in this arena.

III. Research Gaps

Despite the current research available regarding the theoretical aspects of quantum technology, there still are some lacunae that need addressing:

- There have not been enough studies concerning the practical implementation of quantum technology into defense systems, especially in the Indian setting.
- The strategic effects of quantum technology on India's military policies and future warfare strategies have not been analyzed sufficiently.
- Not enough focus has been placed on the problems of adopting the quantum technology, including infrastructure, costs, regulations, and qualified personnel.
- There is a dearth of information regarding the moral, legal, and geopolitical impacts of quantum warfare, especially from the standpoint of global security practices.

IV. Scope Of The Study

This study examines the role of quantum technologies in transforming the defence sector, with a particular focus on India. It analyzes the strategic applications of quantum computing, communication, and sensing in military operations.

The scope includes an evaluation of India's current capabilities, policy initiatives, and preparedness in adopting quantum technologies. It also explores global developments and comparative perspectives to assess India's position in the international arena.

The study is limited to defence and strategic applications of quantum technologies and does not extend to their civilian or commercial uses.

V. Aims And Objectives

Aim:

To critically assess the role of quantum technologies in shaping the future of warfare and evaluate their strategic implications for India's defence sector.

Objectives:

1. To examine the evolution and fundamentals of quantum technologies in defence.
2. To analyze the strategic importance of quantum technologies for national security.
3. To evaluate India's current capabilities and policy framework in the quantum domain.
4. To assess the impact of quantum technologies on future warfare strategies and doctrines.
5. To recommend measures for strengthening India's preparedness and strategic position in quantum defence technologies.

VI. Hypothesis

Quantum technologies will play a transformative role in redefining warfare by enhancing computational power, secure communication, and surveillance capabilities.

However, India's effective utilization of quantum technologies is constrained by technological, infrastructural, and policy limitations, which may hinder its strategic competitiveness in future warfare.

VII. Research Methodology

This study adopts a qualitative doctrinal research approach, focusing on the analysis of legal, strategic, and policy-oriented materials related to quantum technologies in the defence sector.

Primary Sources:
Government reports, policy documents (such as national quantum missions), defence white papers, and official publications related to India's strategic and technological initiatives.

Secondary Sources:
Scholarly articles, research papers, books, think-tank reports, and expert analyses on quantum technologies and their defence applications.
The methodology aims to provide a critical and analytical understanding of the strategic, legal, and policy dimensions of quantum technologies, offering both descriptive insights and normative recommendations.

Conceptual Framework: The Military Quantum Mission Policy (MQM)

The integration of quantum technologies into the Indian Armed Forces is guided by the Military Quantum Mission (MQM) Policy Framework, released on January 22, 2026, by Chief of Defence Staff (CDS) General Anil Chauhan. This framework serves as a comprehensive roadmap to achieve technological dominance in future battlefields by aligning military objectives with the National Quantum Mission (NQM)

Key Strategic Dimensions

Beyond technical domains, the MQM framework introduces three critical dimensions for operational success:

Civil-Military Fusion: The policy creates a bridge between defense requirements and civilian expertise, involving governing bodies that include members from the government, academia, and the private deep-tech startup ecosystem.

Tri-Service Jointness: Standardized quantum protocols are mandated across the Army, Navy, and Air Force to ensure seamless integration within future Integrated Theater Commands.

Technological Sovereignty: By fostering Atmanirbharta (Self-Reliance), the framework aims to eliminate dependence on foreign Original Equipment Manufacturers (OEMs) for critical security infrastructure.

The framework also addresses the OODA (Observe-Orient-Decide-Act) Loop, positing that quantum computing and enhanced AI will exponentially accelerate decision-making cycles, providing a kinetic advantage in high-intensity combat.

Strategic Assessment Methodology for Emerging Military Technologies

To evaluate the transition from theoretical quantum research to operational military capability, this report utilizes a hybrid methodological approach combining the "Operations Research and Analysis" (ORA) model with the "Risk Filtering, Ranking, and Management" (RFRM) framework.

The SADAF-RW Method for Strategic Analysis

The analysis specifically employs the "Strategic Analysis for the Development of the Armed Forces using the Recursive Way" (SADAF-RW) method. This method minimizes expert judgment by focusing on statistical indicators of technology maturation, budget allocation, and operational readiness. By applying this recursive process, the report identifies the "Technology Readiness Levels" (TRL) of quantum sensing and communication as being closer to military integration (TRL 5-7) than universal quantum computing (TRL 3-4).

Doctrinal Analysis and Qualitative Assessment

Parallel to the quantitative modeling, a qualitative doctrinal analysis is conducted to assess how quantum technologies interact with India's existing military strategies. This includes evaluating the impact of quantum transparency on the "Cold Start" doctrine and the "No First Use" (NFU) policy. This dual-track methodology ensures that the report remains grounded in both technical feasibility and strategic reality, providing a comprehensive assessment for decision-makers.

- **Scientific Foundations and the Taxonomy of Quantum Warfare**

  The comprehension and the understanding of the incorporation of quantum technology in the defence sector is not an easy task to do. It requires a rigorous understanding and analysis of the underlying physics element present in the utility of this quantum technology in warfare. Binary logic and macroscopic physical rules are the foundation of classical computing and sensing. On the other hand, quantum systems use the special characteristics of subatomic particles to reach performance levels that are theoretically impossible to attain by classical methods.

- **The Qubit and Superposition**

  It is pertinent to do an analysis delving deeper into the physics and science that works behind the utility and implementation of quantum technology. The fundamental unit used in this technology is Qubit. The entire technology is being run by this unit solely and it can be distinguished from the normal binary units like 0 or 1. A qubit can exist in a linear combination of both states simultaneously due to the principle of superposition. If we want to represent this Qubit in a mathematical formula, it would be:

  $$|\Psi>= \alpha 0)+\beta|1)$$

  where α and β are complex numbers representing probability amplitudes, and $\alpha^2 + \beta^2 = 1$. This property allows for a massive expansion of the computational state space. For a system of n qubits, the computer can represent 2^n states simultaneously, enabling the processing of massive classical datasets with an exponential space advantage. In a military context, this permits the simulation of complex battlefield environments and the optimization of logistics that involve millions of variables, far exceeding the capacity of even the most powerful contemporary supercomputers of algorithms, this offers an "unconditionally secure" approach to communication.

- **Categorization of Defence Applications**

  In this regard, the quantum technology used in the warfare can be categorised into four following categories, each contributing a different capability to the modern warfighter:

Domain	Primary capability	Strategic objectives
Quantum sensing	High-precision measurement of magnetic, gravitational, and EM fields.	Detect stealth asset Submarines and underground structures; navigation in GPS denied zones
Quantum computing	Exponential speed-up for optimization, simulation, and factoring.	Faster decision making, drug/ material discovery , and breaking classical encryption
Quantum communication	Secure distribution of cryptographic keys and quantum networking.	Protect command and control and nuclear codes from decryption or interception
Quantum materials	Design of superconductors and topological materials	Fabrication of high frequency devices, advanced sensors and next gen weapons.

- **Quantum Sensing: The Transparency of the Battlefield**

Quantum sensing technology is considered as one of the mature and time fitting technologies used in the warfare in the recent times as it utilizes the quantum sensitivity states to environmental fluctuations, these sensors steadily provides a huge leap in precision which could render the traditional and outdated stealth techniques used in place of it, obsolete and redundant.

- **Anti-Submarine Warfare and the Maritime Domain**

For the Indian navy, one of the biggest threats or dangers is the proliferation of submarines which are stealthy and quiet enough to cause a big ruckus, both conventional as well as the nuclear powered vessels. Traditional anti-submarine warfare (ASW) relies on acoustic detection (SONAR). However, advancements in sound-dampening coatings, ultra-quiet propulsion, and non-reflective mounts have made modern submarines increasingly difficult to track using sound.

On the other hand, we have the quantum magnetometers and gravimeters which offer a non-acoustic alternative to this issue. Submarines are so strong that they can create huge disturbances in the magnetic fields within a minute through its metal hull and motion. These gravity shifts or magnetic abnormalities can be quite sensitively detected by quantum sensors. In order to create an "invisible underwater radar grid," India's DRDO is now developing quantum magnetometers that may be able to detect stealth submarines at depths of up to 200 meters. These sensors might monitor large areas of the IOR when mounted on maritime patrol planes like the P-8I or high-altitude long-endurance (HALE) UAVs, undermining the stealth advantage that gives ballistic missile submarines (SSBNs) their survivability and second-strike credibility.

- **Quantum PNT: Navigation Without GPS**

The reliance of the contemporary armed forces on global positioning satellites such as GPS or NavIC systems represents one of their key vulnerabilities. The GNSS signals are rather weak and vulnerable to jamming or spoofing at contested borders like the Line of Actual Control or when electronic warfare reaches extremely high intensity.

Quantum PNT seeks to emancipate the soldier from the need for satellites. Cold atom interferometry and quantum gyros can enable "inertial navigation" with enough accuracy that a moving platform or a missile can determine its location for weeks without any external references. Quantum atomic clocks are able to provide time-synchronization to within a second loss per billions of years. Such accuracy is essential for the synchronization of distributed sensor nets, frequency hopping communications, and precise guidance of smart weapons without GNSS support.

- **Quantum Radar and the End of Stealth**

India has emerged as a significant player in the development of indigenous QKD systems. On October 19, 2025, the DRDO successfully conducted a 50-km trial in Hyderabad, demonstrating the secure transmission of command-and-control data between the Defence Research and Development Laboratory (DRDL) and Research Centre Imarat (RCI). This system utilizes time-bin QKD technology and achieves over 85% indigenization, reducing dependence on foreign security hardware.

Since the traditional technologies haven't proven to be that useful in dealing with the modern threats in warfare, the quantum radar has emerged to the rescue. Traditional radar systems work by emitting radio waves and detecting their reflections. Stealth aircraft are designed to absorb these waves or deflect them away from the receiver. Quantum radar, or quantum illumination, uses entangled photon pairs. One photon (the idler) is kept at the base, while its entangled partner (the signal) is transmitted. When the signal photon reflects off a target, it can be compared with the idler photon. Because of the quantum correlation, the receiver can distinguish the true signal from background noise, jamming, or decoys with extreme accuracy. This capability potentially nullifies current stealth coatings and electronic countermeasures, fundamentally altering air superiority doctrines.

- **Quantum Communication: Protecting the State's Nervous System**

The era of digitalization has marked the invention of technology and its defence infrastructure, the security of its communication channels becoming the bedrock of its national sovereignty. The current cryptographic standard, based on the mathematical difficulty of factoring large numbers, is under direct threat from the development of quantum computers.

- **The Quantum Key Distribution (QKD) Milestone**

QKD provides means for the exchange of encryption keys using the process of entanglement and decoherence. It ensures that any third party listening in on the transmission will not be able to decrypt the data since any interference with the quantum state will change the quantum state and the attempt at interception would be immediately detected. ISRO has achieved the feat of demonstrating quantum key distribution in free space through 300 meters of distance at SAC, Ahmedabad, which constitutes a breakthrough in this field.

Following that, the joint research efforts of ISRO and PRL have made advancements in quantum entanglement-based quantum key distribution in the atmosphere involving quantum-secure transmission of images and texts. This paves the way for satellite-based quantum communication, wherein the quantum key would be transmitted using satellites to achieve quantum cryptography without any geographical restrictions due to optical fibre limitations in distance.

- **Post-Quantum Cryptography (PQC) and the HNDL Threat**

Although the technology of QKD provides the supreme physical security which is required, it lacks the special quantum hardware because of which the effectiveness of it somewhat lacks. For legacy systems and wide-area networks, India is also pivoting toward Post-Quantum Cryptography (PQC), mathematical algorithms designed to be resistant to both classical and quantum computer attacks.

Global enemies' "Harvest Now, Decrypt Later" (HNDL) approach is the driving force behind the necessity of PQC transition. Adversaries are currently intercepting and storing encrypted data about troop movements, weapon designs, and nuclear command systems with the goal of decrypting it as soon as a sufficiently powerful quantum computer becomes available. The switch to NIST-approved PQC algorithms like CRYSTALS-Kyber and CRYSTALS-Dilithium is an urgent operational requirement for India, where the security of intelligence sources and satellite telemetry is crucial.

- **Quantum Computing: The Strategic Engine of Decision Support**

So far we have already discussed the various Quantum technologies which have been implemented and incorporated in warfare , however another significant variant of the quantum technology which is used and utilised for the strategic improvement in warfare is quantum computing.

Although the Quantum computing system is still in a processing stage, experts have already studied an analysis that if this Quantum computing achieves the purpose and manages to come into force it will create a drastic change and paradigm shift in the Indian defence sector and it will be compatible with the quality of the global market.

- **Operational and Logistic Optimization**

Modern warfare and the defence sector in contemporary times face a lot of complicated problems. Scheduling the flight missions at airports, optimizing supply routes through hostile territory, and managing the logistics of a multi-front conflict involve variables that grow exponentially. In these issues only the quantum computers come to the rescue and intend to optimize the experience by resolving it efficiently. It does its work by potentially reducing the time required for strategic decision-making from hours to seconds. NITI Aayog's roadmap suggests that by 2035, quantum computing will redefine energy and logistics optimization across the Indian economy, with direct spin-offs for military efficiency.

- **Materials Science and Drug Discovery**

As we already have seen , quantum computers are the new future for the Indian defence sector and warfare. The progress of technology has brought us so many new changes which have not only been able to give birth to artificial intelligence and make our work easier rather it has drastically brought changes to the most important sectors like that of defence sectors or medical sector or even the academically we have got so many inventions which have made the work efficient. The ability of quantum computers to simulate molecular interactions at the atomic level allows for the design of new materials with specific military applications. This includes higher-energy propellants for missiles, stronger and lighter armor materials, and high-temperature superconductors. Furthermore, in the event of biological warfare or pandemics, quantum-accelerated drug discovery could identify therapeutic candidates by simulating molecular interactions between proteins and drugs with unprecedented speed.

VIII. India's Strategic Roadmap: The National Quantum Mission (NQM)

India has come a long way through its technological advancement and its implementation of quantum technology in the warfare and defence sector is commendable and the need of the hour to combat our enemies, especially the terrorists of different countries. We also have seen how the DRDO in India has managed to come up with latest innovations to make the defence sector in India stealthy and to enhance the strength of it so that it can fight with the enemies. Our nation has skillfully invented various technologies to deal with the same. To maintain strategic autonomy and prevent a technological gap with global powers, the Government of India launched the National Quantum Mission (NQM). This mission focuses on the indigenous development of quantum computers, secure communications, and high-sensitivity sensors.

Institutional Excellence and Infrastructural development in Indian defence sector

DRDO has established a robust ecosystem for quantum research, highlighted by the inauguration of the Quantum Technology Research Centre (QTRC) at Metcalfe House in New Delhi in May 2025. This facility serves as a critical hub for developing sovereign technologies in lasers, atomic clocks, and quantum sensors. Complementing this is the DRDO Young Scientist Laboratory for Quantum Technologies (DYSL-QT) in Pune, where researchers under the age of 35 lead breakthroughs in quantum computing and communications. Furthermore, DRDO has launched 15 Industry-Academia Centres of Excellence (DIA-CoEs) across premier institutes like the IITs and IISc to bridge the gap between academic research and battlefield application.

Landmark Achievements in Quantum Communication

DRDO has achieved several world-class milestones in Quantum Key Distribution (QKD) and secure networking:

1. **Hyderabad QKD Trial (2025):** DRDO successfully conducted a 50-km QKD trial between the Defence Research and Development Laboratory (DRDL) and Research Centre Imarat (RCI). This system, which utilized over 85% indigenous components, demonstrated secure transmission of command-and-control data for tri-services operations.
2. **Entanglement-Based breakthrough (2025):** In June 2025, DRDO and IIT Delhi demonstrated free-space quantum secure communication using quantum entanglement over a distance of more than one kilometer. This achievement is a game-changer for future warfare, providing fundamentally unbreakable encryption without the need for physical fiber optics.
3. **Intercity Fiber Links:** DRDO previously established India's first intercity quantum link between Vindhyachal and Prayagraj over 100 km of commercial-grade fiber.

Breakthroughs in Computing and Sensing

DRDO's research extends into the most complex domains of quantum physics to provide the military with a decisive edge:

6-Qubit Quantum Processor: In August 2024, scientists at DYSL-QT, in collaboration with TIFR and TCS, completed end-to-end testing of a 6-qubit superconducting quantum processor.

This project validated the entire hardware-software stack, from the physical qubits to the cloud-based interface.

Anti-Submarine Warfare (ASW): DRDO is developing high-sensitivity quantum magnetometers capable of detecting minute picotesla-level magnetic disturbances caused by submarine hulls at depths of 100 to 200 meters. These sensors can be mounted on P-8I aircraft or drones to create an "invisible underwater radar grid," rendering traditional stealth techniques obsolete.

Precision Navigation: To operate in GPS-denied environments, DRDO is advancing quantum gyroscopes and atomic clocks. These systems offer drift rates significantly lower than conventional technology, ensuring precision timing and navigation for missiles and autonomous fleets.

Through the National Quantum Mission and its focus on Atmanirbhar Bharat, DRDO is positioning India as a global leader, securing the nation's critical infrastructure, including defense networks and financial systems, against the quantum threats of tomorrow.

- **Thematic Hubs (T-Hubs) and Institutional Roles**

The NQM is structured around four Thematic Hubs (T-Hubs), which serve as centralized points for R&D and industry-academia collaboration.

1. **Quantum Computing (IISc Bengaluru**): as we know that several technologies have been invented due to the tireless efforts of many universities and IISc Bengaluru is also one of them. The goal of IISc Bengaluru's Foundation for QC Innovation (FQCI) is to create 50–1000 physical qubit processors employing photonic and superconducting platforms. With an emphasis on neutral atom systems and silicon-based electron spin qubits, it manages 52 researchers across 21 institutes.
2. **Quantum Communication (IIT Madras)**: The Samgnya Technologies Foundation focuses on "India's Secure Quantum Communication". This includes developing 10 Gbps Post-Quantum IP Encryptors (PIPETA), space-ground integrated QKD systems (SBQKD), and nationwide trusted-node-free hybrid networks.
3. **Quantum Sensing & Metrology (IIT Bombay):** The Qmet Tech Foundation focuses on high-precision devices, including atomic clocks and nanopositioners, which are vital for both civilian and strategic navigation.

IX. The Role Of The Indian Army And DRDO

The establishment of a specific laboratory on the quantum technology by the Indian army is considered very significant as it promises to change the defence sector by implementing the good sides of the technology. This Quantum laboratory has been established in the military College of communication in engineering which is situated in Madhya Pradesh. Laboratory is supported and funded by the national security council secretariat. The Nobel work that this laboratory those is the optimization of the quantum technology sphere heading research on the sensor and computing technology used in the defence sector to enhance its use.

The goal is to leapfrog into next-generation communication systems for the Armed Forces, transforming legacy cryptography into quantum-safe standards

Complementing this is the DRDO Young Scientist Laboratory for Quantum Technologies (DYSL-QT) in Pune. DYSL-QT has achieved milestones in entanglement-assisted quantum secure communication, with successful trials conducted at Hyderabad between the Defence Research and Development Laboratory (DRDL) and Research Centre Imarat (RCI). These trials validated the detection of eavesdropping over a 12 km range using time-bin QKD technology.

X. Geopolitical Competition And The "Quantum Race”

It is pertinent to go beyond the Indian scenario and to have a look at the global perspective in respect of the quantum technology and how it has manage to achieve the purpose which intensed to achieve in the global defence sector. Strategic implications of this technology is intensified by the continuous tug of war between China and the United States.

As we all know that China is a very powerful country and its leading advancement in the technology has allowed it to come up with very innovative inventions on the quantum technology for which they take pride in.

China's centrally governed system has made them leaders in quantum communication technologies with their 12,000 km quantum communication network and two quantum satellites. On the other hand, the United States has remained at the forefront of quantum computing due to their entrepreneurial environment with start-ups and academic research institutions.

- **Quantum Power Parity**

One important idea that has recently gained attention in geopolitics is that of "Quantum Power Parity." This represents a scenario where the two opposing states have the necessary quantum power to sense invisible forces, compute threats, and use QKD to ensure their secrets remain safe. Nevertheless, the concept of quantum power parity is viewed as being more unstable than nuclear parity. While the nuclear warheads can be counted and validated by the relevant treaties, the quantum power cannot be verified because it has dual usage and is difficult to detect due to its commercial application nature.

- **Regional Implications for India**

The strategic awareness about the importance of QT by China's PLA is a clear threat to India. The advances made by China in satellite QKD and underwater detection might provide it with an edge in the Himalayan region and Indian Ocean. In case China is able to decipher the signals of the Indian military without compromising on its own security using QKD, then the concept of the Cold Start strategy adopted by India and its border policy would become vulnerable.

Moreover, the use of robot soldiers by China at LAC, who are operated wirelessly with AI-powered coordination, might become more effective by implementing QKD and quantum-enhanced AI. It becomes imperative for India to develop its quantum capabilities and attain parity with China.

- **International Collaboration: The India-US Tech Partnership**

As a response to changing dynamics of power relations, India has increased its technological collaboration with the US. The Initiative on Critical and Emerging Technology (iCET), initiated in May 2022, and its upgraded version, which was planned for 2025 under the title of the "TRUST" (Transforming the Relationship Utilizing Strategic Technology) program, is a sign of moving towards a "Major Defense Partnership."

XI. TRUST And COMPACT Initiatives

The new TRUST initiative, which came into effect during PM Modi’s visit to Washington in February 2025, will build upon the initiatives undertaken by iCET with regard to Artificial Intelligence (AI), semiconductors, and quantum technology. In addition, it involves an important element called "U.S.-India COMPACT" (Catalyzing Opportunities for Military Partnership, Accelerated Commerce & Technology).

Specific outcomes relevant to quantum warfare include:

1. **Shakti Fab:** A collaboration between the US Space Force, Bharat Semi, and 3rdiTech to build a chip-making facility in India. The fab will manufacture GaN and SiC chips, which form the base for state-of-the-art sensors, high-power electronics, and quantum-compliant communication systems.
2. **Indus Innovation:** A new innovation bridge modeled after the successful INDUS-X platform, designed to foster academic and industry partnerships in space, biotech, and quantum computing.
3. **Supply Chain Security:** Joint initiative aimed at cutting down dependence on China when it comes to the supply of critical minerals such as lithium and rare earths as well as pharmaceutical ingredients.

XII. Hardware Gaps And The Path To 2035

Despite strong scientific progress, India faces significant hurdles in building a self-reliant quantum hardware ecosystem. NITI Aayog's 2025 roadmap, "Transforming India into a Leading Quantum-Powered Economy," identifies several "larger gaps" that must be addressed to achieve "strategic autonomy".

- **Critical Hardware Dependencies**

Currently, India is heavily dependent on imports for the peripheral components required to run quantum systems. These include:

1. **Cryogenics**: Cryogenics dilution refrigerators are required in order to keep superconducting qubits extremely close to absolute zero temperature. At present, India does not have the capability of indigenous production of such cryogenic equipment.
2. **Optics and Lasers**: The use of stabilized lasers and ultra-high purity materials such as isotopically purified atoms or unique types of crystals is needed for cold atom-based quantum sensing devices and photonic quantum computers.
3. **Engineering Expertise:** A shortage of expertise in microwaves, nanotechnology, and software/hardware co-engineering can be observed.

XIII. Goals For National Sovereignty

The NITI Aayog roadmap sets an ambitious goal for India to become a "net exporter" of quantum technologies by 2035. To achieve this, the mission emphasizes:

- **Manufacturing Hubs:** Building world-class R&D and manufacturing centers to produce indigenous quantum hardware.
- **Military-Industrial Complex:** Leveraging programs like iDEX (Innovations for Defence Excellence) to accelerate the adoption of quantum hardware in the military.
- **IP Generation**: Increasing investment in basic science (currently at 0.65% of GDP) to secure patents and a share of the global quantum IP market, where India currently does not rank in the top 10.

XIV. Implications Of Quantum Computing For Warfare

The use of quantum technologies within the defense sector would have a wide range of implications on the operations and processes of the Armed Forces.
End of Stealth?

The most significant consequence of quantum sensors would be the end of conventional stealth technology. The United States and other countries have spent tens of billions of dollars on stealth aircraft (F-35s, B-21 bombers), and quantum radar and magnetometers could be able to see through them. This has implications for India as well because any stealth aircraft project (such as the AMCA fighter plane) would be futile because their technology can only outperform legacy radar and detection systems.

- **Reduction in OODA Cycle Time**

OODA is an acronym used to denote the observation, orientation, decision, and action phases in the decision cycle. The four-stage model was proposed by military strategist Colonel John Boyd. With quantum sensors, quantum computers, and quantum enhanced AI, this loop would be compressed significantly. For example, in a hypothetical conflict with hypersonic missiles or autonomous drones, the party with superior quantum sensors would be at a kinetic advantage in terms of observation and decision.

- **Nuclear Stability and the Second-Strike Paradox**

Quantum sensing's ability to track SSBNs introduces a "Second-Strike Paradox." Traditionally, SSBNs are considered the most survivable leg of the nuclear triad because they are hidden in the deep ocean. If quantum gravimeters and magnetometers render them detectable, the "assured" part of Mutually Assured Destruction (MAD) is undermined. This could be destabilizing if a nation perceives that its second-strike capability is vulnerable to a preemptive strike. For India, which maintains a "No First Use" policy, ensuring the invulnerability of its Arihant-class submarines through either quantum-resistant countermeasures or superior counter-detection is critical to maintaining a credible deterrent.

XV. Conclusion: Strategic Recommendations For India

The time when the quantum challenge and advantage were merely concepts is long gone; they have become operational realities. In response, any failure of India to safeguard its military communication lines and improve its ability to sense will create a massive strategic vacuum.
In order to secure strategic superiority in the quantum age, the following are necessary approaches:

- **Phase-wise Implementation of PQC Technology:** It will be imperative for the Indian military authorities to carry out a thorough cryptographic evaluation in order to transition into Post-Quantum Cryptography in an organized manner.

Utilizing QKD Technology: Strategic communication routes, especially those dealing with nuclear command and control and diplomatic communication, must be protected using terrestrial and space QKD technology.

- **Indigenous Hardware Fabrication:** In order to reduce India's dependency on external technologies and avoid merely becoming another customer, efforts must be made for the development of hardware such as GaN chips and dilution refrigerators. The "TRUST" project and Shakti fab come handy here.

Q-Computing and AI Synergy: It is important that quantum computing technology be combined with AI technology in order to produce autonomous weapon and threat detection systems.

By aggressively pursuing the objectives of the National Quantum Mission and leveraging its strategic partnerships, India can transform the quantum challenge into a competitive advantage, ensuring its sovereignty and operational security in the contested landscape of future warfare. The window for global leadership is open, and for India, the "clock is ticking" toward a quantum-powered future.

XVI. REFERENCES:

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[8] Man-portable air defence systems (MANPADS) are surface-to-air missiles small enough to be fired from the shoulder or from a small stand. The portability of these weapons and their potential effectiveness against large and slow aircraft, such as civilian airliners, creates a significant risk of terrorist acquisition and use. There have been a number of cases of actual or attempted use of such weapons against civilian aircraft. Moreover, for Russia, the use of these weapons by opposition fighters in Chechnya has led to the loss of significant numbers of helicopters and fixed-wing military aircraft. Anthony, I., Reducing Threats at the Source: A European Perspective on Cooperative Threat Reduction, SIPRI Research Report no. 19 (Oxford University Press: Oxford, 2004).

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[10] Supra 9

[11] Ibid. 10

[12] Infra 11