



Quantum Satellite

For Prelims: [Quantum satellite](#), [Quantum Physics](#), [Encryption](#), [Quantum Entanglement](#), [India](#), [Make in India](#), [Skill India](#), [International Telecommunication Union](#)

For Mains: [National Quantum Mission](#), Quantum Technologies and their Implications

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Why in News?

India's [National Quantum Mission \(NOM\)](#) aims to launch a [quantum satellite](#) in 2-3 years, advancing secure communications through [quantum physics](#). This initiative positions India at the forefront of next-gen technology.

What is a Quantum Satellite?

- **About:** A quantum satellite is a communications satellite that employs quantum physics to secure its signals, making it highly resistant to interception.
 - It utilizes **quantum cryptography** (a method that uses quantum mechanics to encrypt and transmit data), particularly [Quantum Key Distribution \(QKD\)](#), to protect data by detecting eavesdropping during transmission.
- **Quantum Cryptography:**
 - **Encryption Basics:** Classical [encryption](#) methods, like the *Caesar cipher*, messages are encoded in a **secret code**. Without the key, it is not possible for eavesdroppers to decipher the message.
 - However, these methods are vulnerable to **quantum computers**, which could crack the code much faster than traditional supercomputers.
 - **Quantum Encryption:** It uses **quantum key distribution (QKD)**, to secure messages.
 - In **Quantum Measurement**, when a quantum system, such as a **photon (a tiny particle of light)**, is measured, its state changes.
 - If an eavesdropper attempts to **measure the photons carrying a key**, this **interference alters the state of the photons**. As a result, the legitimate parties communicating will immediately detect that the key has been compromised.
 - Additionally, [quantum entanglement](#) ensures that **any change to one photon instantly affects the other**, making it impossible for an eavesdropper to alter the information without detection.
 - This makes QKD offer "**unconditional security**" by detecting any interception, ensuring secure communication.
- **Global Developments in QKD:** China currently operates the **world's largest QKD network**, which includes three quantum satellites and four ground stations.
 - India is advancing its quantum communications experiments, with plans for a satellite-based QKD network. Studies by the Raman Research Institute, Bengaluru, suggest that the [Indian Astronomical Observatory in Hanle, Ladakh](#), offers ideal conditions for

such a system.

- [Indian Space Research Organisation \(ISRO\)](#) has successfully demonstrated free-space **Quantum Communication** over a distance of 300 m.
- The [United Nations \(UN\)](#) has designated the year **2025 as the 'International Year of Quantum Science and Technology'** to increase public awareness of the importance of quantum science and its applications.

What are the Limitations of Quantum Key Distribution?

- **Technological Maturity:** The technology is still in the **experimental phase in India**, and commercial implementation of large-scale QKD networks is not yet feasible.
- **Infrastructure Costs:** Implementing QKD requires **specialized hardware and infrastructure**, which increases costs compared to traditional cryptography methods.
- **Integration:** Integrating QKD with **existing communication networks** and ensuring compatibility with classical encryption systems presents a significant technical challenge.
- **Lack of Authentication:** QKD doesn't provide a **reliable means to authenticate the source of the transmission**, making it vulnerable to potential attacks where an **adversary could impersonate a legitimate party**.

What is the National Quantum Mission (NQM)?

- **About:** The NQM, launched in 2023 with a Rs. 60,000 crore investment from 2023-24 to 2030-31, aims to advance **Quantum Technologies in India** and position India as a global leader in **Quantum Technologies and Applications (QTA)**.
- **Objective:** The NQM aims to develop quantum computers (build intermediate-scale quantum computers with 50-1000 physical **qubits (quantum bits)** over 8 years), utilizing **superconducting and photonic platforms**.
 - It will establish **satellite-based secure quantum communications** within 2000 km in India and internationally.
 - The NQM will support inter-city quantum key distribution over 2000 km and develop multi-node quantum networks. It also focuses on creating atomic clocks for precision applications.
- **Significance:** NQM aims to make **India a global leader in quantum technologies**, surpassing classical physics limits with advanced capabilities beyond current systems.
- **National Priorities:** The NQM aligns with and supports national priorities like [Digital India](#), [Make in India](#), [Skill India](#), [Start-up India](#), and [Self-reliant India](#).
- **Implementation:** The Mission will establish four **Thematic Hubs** in collaboration with top academic and National R&D institutes. These hubs will focus on [Quantum Computing](#), [Quantum Communication](#), Quantum Sensing & Metrology, and [Quantum Materials & Devices](#).
 - These hubs will drive new knowledge and research, advancing quantum technology.
- **Sectoral Impact:** The Mission will greatly benefit sectors such as **communication, health, financial services, energy, and more**. Specific applications include Drug design, Space exploration, and Banking and security.

NATIONAL QUANTUM MISSION

Aims to put India among the top six leading nations involved in the R&D in quantum technologies

■ Presently, R&D works in quantum technologies are underway in the US, Canada, France, Finland, China and Austria ■

■ **Duration:** 2023-24 to 2030-31

■ **Nodal Ministry:** Ministry of Science & Technology

■ **Highlights of the Mission:**

- Four Thematic Hubs (T-Hubs) in different domains across the country
- Wide-scale applications ranging from healthcare and diagnostics, defence, energy and data security

- Strengthening of indigenously building quantum -based computer
- Help develop magnetometers with high sensitivity in atomic systems and atomic clocks
- Support design and synthesis of quantum materials

A huge boost to National priorities like digital India, Make in India, Skill India, Stand-up India, Start-up India, Self-reliant India and SDGs

Quantum Technology

■ Works by using the principles of quantum mechanics (the physics of sub-atomic particles), including quantum entanglement and quantum superposition ■

Quantum Superposition

The ability of a quantum system to be in multiple states simultaneously

While digital computers store data as bits (the ones and zeros of binary), quantum computers use qubits that exist as one, zero or both at the same time

This superposition state creates a practically infinite range of possibilities, allowing for fast simultaneous and parallel calculations

Quantum Entanglement

It means the two members of a pair (Qubits) exist in a single quantum state

If you change the properties of one of them, the other changes instantly

This can be used to create a secure encryption key in quantum cryptography

If an eavesdropper tries to intercept the transmission, the entangled state of the particles will be disturbed, making the attempt detectable



Way Forward

- **Post-Quantum Cryptography:** Due to limitations of QKD, some experts recommend using post-quantum cryptography, which combines **quantum-resistant algorithms with classical encryption techniques**, offering an alternative to the hardware limitations of QKD.
- **Quantum Authentication:** Creation of quantum authentication protocols that ensure both encryption and identity verification will be key. This will close the gap in the security chain and make the system resistant to impersonation and data breaches.
- **Miniaturisation and Robustness:** Developing **smaller, energy-efficient, and cost-effective quantum** devices for **scalable deployments** will make the technology accessible across industries like defense and healthcare.
- **International Collaboration:** Global cooperation is crucial for a standardised and interoperable quantum communication network. India should influence international standards and, through platforms like the [International Telecommunication Union \(ITU\)](#), ensure its quantum systems are interoperable and meet global security requirements.

Drishti Mains Question:

Discuss the objectives and significance of the National Quantum Mission and its potential impact on India's technological ecosystem."

UPSC Civil Services Examination Previous Year Question (PYQ)

Prelims

Q. Which one of the following is the context in which the term "qubit" is mentioned?

- (a) Cloud Services
- (b) Quantum Computing
- (c) Visible Light Communication Technologies
- (d) Wireless Communication Technologies

Ans: (b)

Exp:

- **Quantum Supremacy**
 - Quantum computers compute in 'qubits' (or quantum bits). They exploit the properties of quantum mechanics, the science that governs how matter behaves on the atomic scale.
- **Hence, option (b) is correct.**

Mains

Q. "The emergence of the Fourth Industrial Revolution (Digital Revolution) has initiated e-Governance as an integral part of government". Discuss. (2020)

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