# Quantum Technology and Military Applications

September 2025

# Contents

# Part I

# Foundations

# Chapter 1

# Key Definitions

## 1.1 Core Terms

- **Quantum Technology (QT):** Uses quantum properties like entanglement, superposition, and tunneling for real-world applications.
- **Dual-use technology:** Serves both civilian and military purposes.
- **Quantum Warfare (QW):** Warfare enhanced by QT across all domains.
- **Quantum Attack:** Exploiting quantum tools to break or disrupt security.

## 1.2 Taxonomy of QT

- **Quantum Computing & Simulation** – Digital & analog computers, simulators.
- **Quantum Communication & Cryptography** – Quantum networks, QKD, post-quantum cryptography.
- **Quantum Sensing & Metrology** – Magnetometers, gravimeters, clocks, radar, imaging.

## 1.3 Impact Categories

- **Must Have:** Essential for security (e.g., post-quantum cryptography).
- **Effectiveness:** Enhances current tools (e.g., quantum AI, optimization).
- **Precision:** Better measurement accuracy.
- **New Capabilities:** Enables things never before possible (e.g., quantum radar).

# Chapter 2

# Quantum Technology Overview

Categories and foundational principles of quantum technology from the second quantum revolution.

## 2.1 Quantum Information Science

- Information science linked to quantum physics.
- Core concepts: qubits, quantum superposition, quantum entanglement, no-cloning theorem.
- Basis for quantum computing, communication, and sensing.

## 2.2 Quantum Computing

- Types: Digital QC, Analogue QC, Quantum Simulators.
- Evolutionary stages:
    1. Component QC (CQC)
    2. Noisy Intermediate-Scale QC (NISQ)
    3. Fault-Tolerant QC (FTQC)

## 2.3 Quantum Communication & Cryptography

- Quantum Networks
- Quantum Key Distribution (QKD)
- Post-Quantum Cryptography (PQC)
- Quantum Random Number Generators (QRNG)

## 2.4 Quantum Sensing & Metrology

- Most mature area: timing, sensing, imaging.
- Includes: quantum electric/magnetic/inertial sensors, quantum clocks, RF antennas, imaging systems, radar technology, other advanced sensors.

# Chapter 3

# Recent Milestones in Quantum Computing

| Date | Development | Details / Significance | Source |
|---|---|---|---|
| Sep 2025 | Quantum Motion: first full-stack silicon CMOS quantum computer | Delivered to UK's National Quantum Computing Centre — a step toward scalable, manufacturable hardware. | Quantum Motion |
| Sep 2025 | IonQ frequency conversion to telecom wavelengths | Converts photons from trapped-ion systems into telecom bands → key for quantum internet over fiber. | IonQ |
| Jul 2025 | Japan's first homegrown superconducting QC | Built entirely from domestic components at RIKEN — boosts national quantum sovereignty. | LiveScience |
| Jul 2025 | Cryogenic amplifier breakthrough (TWPA) | Reduces amplifier heat emissions by factor of 10,000 — crucial for scaling cryogenic quantum systems. | LiveScience |
| Apr 2025 | Fujitsu & RIKEN: 256-qubit superconducting QC | Quadruples scale of their 2023 machine; roadmap to 1,000 qubits by 2026. | SpinQuanta |
| Apr 2025 | DARPA scaling initiative | 15 companies engaged to scale multiple hardware platforms (superconducting, photonic, trapped ions, neutral atoms). | NextGov |
| Mar 2025 | Pasqal + NVIDIA CUDA-Q integration | Enables hybrid quantum-classical workflows, integrating quantum systems with GPU toolchains. | Reuters |
| Feb 2025 | Microsoft Majorana 1 topological chip | Introduces "topoconductor" material — aims for higher fault tolerance and scalability. | Microsoft |

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|---|---|---|---|
| 2025 | D-Wave claims quantum supremacy (annealing) | Reported outperforming supercomputers in a materials simulation task with quantum annealing. | Financial Times |
| 2025 | IQM raises $300M+ funding | Expanding hardware R&D and partnerships with national labs. | IQM |

# Part II

# Applications and Military

# Chapter 4

# Applications of Quantum Computing

Major application areas of quantum computing are covered in the following subsections.

### 4.0.1 Quantum Simulations

chemistry, materials science, drug discovery

### 4.0.2 Quantum Cryptoanalysis

breaking RSA, ECC, symmetric cryptography

### 4.0.3 Quantum Searching & Walks

faster searches in large datasets.

### 4.0.4 Quantum Optimization

logistics, traffic, financial modelling.

### 4.0.5 Quantum Linear Algebra

faster equation solving (HHL algorithm).

### 4.0.6 Quantum Machine Learning & AI

enhanced ML, neural networks, pattern recognition.

# Chapter 5

# Military Applications

Applications of quantum technology to defence and security based on the paper [1]

### 5.0.1 Quantum Cybersecurity

Defence & attack capabilities.

### 5.0.2 Quantum Computing

Enhanced computational power for defence simulations.

### 5.0.3 Quantum Communication

Security & technical applications (QKD, networks).

### 5.0.4 Quantum PNT

Precision navigation & timing without GPS.

### 5.0.5 Quantum ISTAR

Earth's surface & underground surveillance, advanced imaging.

### 5.0.6 Quantum Electronic Warfare

Radar and lidar disruption.

### 5.0.7 Quantum Radar & Lidar

Stealth detection.

### 5.0.8 Quantum Underwater Warfare

Submarine detection with gravimeters/magnetometers.

### 5.0.9 Quantum Space Warfare

Secure satellite networks, timing systems.

### 5.0.10 Chemical & Biological Simulations

Detection and defence research.

### 5.0.11 New Materials Design

Improved armour, energy systems.

### 5.0.12 Brain Imaging & Human

Machine Interfaces – Potential long-term uses.

# Chapter 6

# Recent Advances by Application Area

| Application Area | Development | Details / Significance | Source |
|---|---|---|---|
| Quantum Simulations | Hybrid quantum + AI boosts molecular modeling | University of Michigan researchers combine quantum and AI for more accurate simulations. | Interesting Engineering |
| Quantum Simulations | Scalable chemistry simulation with error correction | Quantinuum demonstrates end-to-end chemistry workflow with QEC. | Quantinuum |
| Quantum Simulations | First-principles simulation of cavity-coupled molecules | Strong light–matter coupling modeled at quantum level. | Quantum Zeitgeist |
| Quantum Simulations | New approach to quantum chemistry equations | Improves accuracy of molecular simulations. | Phys.org |
| Quantum Machine Learning & AI | D-Wave quantum-AI developer tools | New toolkit integrates quantum systems into AI training. | D-Wave |
| Quantum Machine Learning & AI | QKAR chip design optimization | Australian team boosts semiconductor design efficiency by $\sim 20\%$. | Tom's Hardware |
| Quantum Machine Learning & AI | ML for quantum circuit optimization | AlphaTensor-Quantum reduces gate overhead and improves efficiency. | QuSoft |
| Quantum Optimisation | Quantum ML in finance / portfolio optimization | Emerging QML techniques applied to smart investing and portfolio optimization. | Finextra |

# Chapter 7

# Recent Developments in Quantum Defence Applications

| Date | Application | Development | Source |
|---|---|---|---|
| Sep 2025 | Quantum Communication / Networks | IonQ demonstrates photon conversion to telecom wavelengths, enabling quantum-secure networking over existing fiber. | Investors.com |
| Sep 2025 | Quantum Cybersecurity / Networks | Rigetti wins U.S. Air Force contract to build hybrid superconducting-optical quantum network nodes. | Barron's |
| Jul 2025 | Quantum PNT & Sensing | Honeywell awarded U.S. government contracts for quantum sensors supporting PNT & ISR under DoD's transition program. | Honeywell |
| Jun 2025 | Quantum PNT (Maritime) | Q-CTRL's maritime quantum navigation (dual gravimeter) tested aboard Australian Navy vessel in first defence sea trials. | Q-CTRL |
| May 2025 | Strategic Threat Assessment | U.S. Defense Intelligence Agency warns rivals are nearing operational deployment of quantum technologies. | Quantum Insider |
| May 2025 | Policy / Strategy | Just Security op-ed urges U.S. strategy to prioritize quantum sensors as the most immediate defence advantage. | Just Security |

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|---|---|---|---|
| Apr 2025 | Quantum PNT & Navigation | DARPA awards $24.4M to Q-CTRL to develop quantum navigation sensors resilient to jamming/spoofing. | Q-CTRL |
| Apr 2025 | Quantum Navigation Prototype | Lockheed Martin and DIU contract to prototype quantum inertial navigation systems for defence platforms. | Lockheed Martin |
| Jan 2025 | Quantum Radar & Electronic Warfare | HENSOLDT to support DLR in optimizing quantum radar for defence applications. | Quantum Insider |
| Jan 2025 | Quantum Radar / ISAC Integration | Research proposes integrating quantum radar (quantum illumination) into integrated sensing & communications (ISAC) architectures. | arXiv |

## Executive Summary

We are entering a critical inflection point in technological history. The convergence of **Quantum Computing**, **Artificial Intelligence (AI)**, and **Security** is not a distant future—it is the emerging present.

As quantum algorithms grow more capable, AI systems more autonomous, and cyber threats more complex, we must ask: *how do we engineer trust, resilience, and intelligence at the frontier*?

The diagram below illustrates the overlap between these domains and the interdisciplinary challenges that arise at their intersections—from **Quantum AI** to **Post-Quantum Cryptography** and **AI-driven cyber defense**.

# Part III

# Strategy and Policy

# Chapter 8

# Quantum Strategy Roadmap

Roadmap for national defence adoption of quantum technology:

1. Identification – Assess technological and scientific risks vs advantages.
2. Development – Support R&D, prototyping, certification.
3. Implementation & Deployment – Reach operational capability, adapt doctrines and strategies.

# Chapter 9

# TRL & Time Horizon

Technology Readiness Levels and projected timelines.

| **Technology** | TRL | Horizon |
|---|---|---|
| **Quantum Computer (annealer)** | 4–5 | 2030 |
| **QKD (satellite)** | 7–8 | 2025–2030 |
| **PQC** | 7–8 | 2025 |
| **Quantum Communication Network** | 1–3 | 2030–2035 |
| **Quantum Inertial Navigation** | 4–5 | 2025–2030 |
| **Quantum Clocks** | 4–6 | 2030 |
| **Quantum Radar** | 1–2 | Long-term |
| **Quantum RF Antenna** | 4 | 2025–2030 |
| **Quantum Magnetic & Gravity Sensing** | 5–6 | 2025 |
| **Quantum Imaging** | 5 | 2025–2030 |

# Chapter 10

# Summary of Recent Quantum Policy News

| Region | Date | Policy / Action | Link |
|---|---|---|---|
| USA | Sep 2025 | White House preparing executive actions to accelerate quantum tech and PQC adoption in federal agencies. | NextGov |
| USA | 2025 | Bipartisan NDAA amendment (SA 3684) requires national PQC migration strategy, pilot programs by 2027, and cost surveys. | Quantum Computing Report |
| USA | 2025 | Export controls imposed on advanced quantum technologies to restrict adversarial access. | MIT QIR |
| UK | 2025 | £670m, 10-year government investment plan in quantum computing. | NQCC |
| UK | 2025 | National "Compute Roadmap" includes AI and quantum compute capacity through 2030. | Gov.uk |
| UK | Mar 2025 | PQC Migration Roadmap: identification of systems by 2028, major overhauls by 2031, full adoption by 2035. | NCSC |
| EU | Jul 2025 | EU pushes for private capital to boost quantum tech ambitions by 2030, supplementing public funding. | Reuters |
| EU | Ongoing | EuroQCI project continues rollout of European Quantum Communication Infrastructure. | EU Commission |
| India | 2023–2025 | National Quantum Mission ($730M) supporting quantum computing, communication, sensing, and materials. | DST India |
| India | 2025 | First full-stack 25-qubit domestic quantum computer (QpiAI-Indus) deployed. | Times of India |

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|---|---|---|---|
| Australia | 2025 | National Quantum Strategy (2023–2033) updated milestones, including PQC guidance and hybrid quantum-classical projects. | Cyber.gov.au |
| Multilateral | Sep 2025 | U.S.–UK "Tech Prosperity Deal" – $31B joint initiative for AI and quantum cooperation. | Quantum Insider |
| Multilateral | Sep 2025 | CERN partners with Single Quantum and Qunnect to launch new quantum networking lab. | Quantum Insider |
| Multilateral | 2025 | Business Software Alliance (BSA) publishes global quantum policy agenda (infrastructure, workforce, PQC, export control). | BSA.org |

# Chapter 11

# Recent Quantum Computing Policy Developments

| Policy / Action | Description | Link |
|---|---|---|
| White House executive actions on quantum tech | The U.S. administration is preparing executive actions to accelerate quantum computing and broader quantum technology adoption in federal agencies. | NextGov |
| U.S.–UK Tech Prosperity Deal | The U.S. and UK signed a Technology Prosperity Deal to strengthen collaboration in deep tech, including quantum computing. | The Quantum Insider |
| UK investment in quantum computing (£670m) | The UK government announced a 10-year funding package worth £670 million to support quantum computing development. | NQCC |
| UK Compute Roadmap | The UK "Compute Roadmap" outlines major investments in AI and quantum computing infrastructure through 2030. | Gov.uk |
| Full-stack silicon CMOS quantum computer deployed (UK) | A full-stack silicon quantum computer using spin qubits was delivered to the National Quantum Computing Centre. | Quantum Motion |
| U.S. export controls on quantum technologies | The U.S. government introduced export controls on quantum computing and related technologies. | MIT QIR Policy |
| Bipartisan U.S. quantum legislation | Representatives Subramanyam and McGuire introduced bipartisan legislation to safeguard infrastructure and strengthen quantum readiness. | House.gov |

# Chapter 12

# Latest Government Policy on Post-Quantum Cryptography (PQC)

## 12.1 Recent PQC Policy Developments

| Policy / Action | Description | Link |
|---|---|---|
| Executive actions on quantum & PQC (U.S.) | The White House is preparing executive actions to accelerate quantum technology and PQC adoption across federal agencies. | NextGov |
| Senate amendment for PQC migration strategy (SA 3684) | A bipartisan amendment to the FY 2026 NDAA requires a national PQC migration strategy, pilot upgrades by 2027, cost surveys, and progress reports. | Quantum Computing Report |
| NSA / CNSS Policy 15 (March 2025) | NSA released CNSS Policy 15 identifying quantum-resistant algorithms for use in national security systems. | NSA.gov |
| UK / NCSC migration timelines | NCSC published PQC migration timelines: identification by 2028, overhaul by 2031, full adoption by 2035. | NCSC.gov.uk |
| UK financial sector guidance (CMORG) | The UK's CMORG issued guidance (April 2025) urging PQC adoption aligned with NCSC's roadmap. | CMORG Guidance PDF |
| DHS PQC roadmap and guidance | DHS issued internal policy directing agencies to inventory and prioritize systems for PQC migration. | DHS.gov |

## 12.2 Key Takeaways

- The U.S. and UK governments are moving from research into binding policies and legislative frameworks.
- Deadlines (2027 for pilots, 2035 for full adoption) are now explicit in both the U.S. and UK.
- Agencies are under pressure to inventory cryptographic systems and plan for migration.
- NSA and NCSC have provided concrete algorithm choices and migration roadmaps.
- Sector-specific guidance (e.g., UK finance) shows PQC policy is spreading beyond central governments.

# Part IV

# Perspectives

# Chapter 13

# Hype vs Reality

- Acknowledge the *quantum hype*.
- Many breakthroughs are still prototypes; scaling up is the main bottleneck.
- Realistic timelines: some breakthroughs (e.g., post-quantum cryptography, QRNG) are already here, while others (e.g., quantum radar) may be decades away.

# Chapter 14

# Ethical, Security, and Peace Implications

- Quantum warfare may alter strategies, doctrines, and treaties.
- Raises ethical concerns: should certain QT be controlled under arms agreements?
- Dual-use technology spreads faster, complicating arms control and international regulation.

# Chapter 15

# Conclusion

- Quantum technology will not create entirely new weapons but will transform warfare by enhancing precision, sensing, and cryptanalysis.
- Countries need a balanced approach: invest, prepare countermeasures, and develop ethical and legal frameworks.

# Chapter 16

# Key Observations

- Quantum computing is now explicitly embedded in both U.S. and UK national technology strategies.
- Policies combine domestic funding (e.g., UK's £670m plan) with international cooperation (U.S.–UK pact).
- Export controls highlight security concerns and a desire to limit adversarial access.
- New legislation and executive orders are shifting quantum from research priority to strategic infrastructure.

# Part V

# Quantum, AI, and Security

## 16.1 Four Strategic Frontiers

### Quantum AI

**Accelerating Intelligence with Quantum Algorithms**

Quantum computing opens new frontiers in machine learning—boosting optimization, search, and pattern recognition. Can we build quantum-enhanced AI models that learn faster, generalize better, and defend autonomously?

### Post-Quantum Security

**Designing Cryptographic Systems for a Quantum-Enabled World**

With Shor's algorithm threatening current public-key cryptography, secure communication demands quantum-resistant algorithms. How can we architect and scale post-quantum cryptographic systems before adversaries gain quantum advantage?

### Hybrid Intelligence Systems

**Combining Classical & Quantum Capabilities to Fortify Decision-Making**

Hybrid architectures—where classical AI and quantum processors work in tandem—may offer a leap in speed and security. How do we build secure, adaptive platforms that operate across this hybrid divide?

### 16.1.1 Threats and Opportunities

**Securing the Strategic Edge in the Quantum Race**

As adversaries develop offensive quantum capabilities, the risk landscape expands—from encrypted data harvesting to quantum-enabled surveillance. What policies, safeguards, and innovation pathways can help allied forces stay ahead?

## 16.2 Looking Ahead

At the intersection of these disciplines lies more than technical innovation—it's a matter of digital sovereignty, intelligence superiority, and national security.

Building secure, intelligent systems in the age of quantum requires cross-sector collaboration, bold research, and an unwavering commitment to ethical foresight.

# Bibliography

[1] Eleni Diamanti, Anthony Leverrier, Philippe Bouyer, Norbert Lütkenhaus, Philippe Grangier, Nicolas Sangouard, Stefano Pirandola, Valerio Scarani, Artur Ekert, John Rarity, Harald Weinfurter, et al. Quantum technologies for military applications. *EPJ Quantum Technology*, 8(19):1–22, 2021.