QETCI

Quantum Ecosystems Technology
Council of India

“UNVEILING THE **INDO-DUTCH** QUANTUM FRONTIER

IN SEARCH OF OPPORTUNITIES TO INTEGRATE ECOSYSTEMS”

Kingdom of the Netherlands

Netherlands
Innovation
Network

Publication Date
June 2025

Commissioned by
Netherlands Innovation Network India
6/50 F Shantipath, Chanakyapuri
New Delhi 110021

Published by
Quantum Ecosystems Technology Council of India (QETCI)
Block C-4, Vindhya Building, IIIT Hyderabad
Hyderabad 500032

Credits
Reena Dayal Yadav, Chief Executive Officer, Quantum Ecosystems Technology Council of India
Shantanu Sharma, Senior Policy Researcher, Quantum Ecosystems Technology Council of India
Abhishrutha Raghavendra, Researcher at Quantum Ecosystems Technology Council of India (until October 2024. Contributed to the report through primary research)

Table of Contents

Foreword

Quantum technology is poised to redefine the future of innovation, offering solutions to some of the most complex challenges across sectors such as cybersecurity, healthcare, finance, and manufacturing. Its potential to surpass the limits of classical computing offers exciting new avenues for growth and transformation. As the global race to harness the power of quantum advances, countries are increasingly focusing on how they can lead in this groundbreaking field.

India and the Netherlands, each with its dynamic quantum initiatives, share a strong foundation for collaboration. The opportunity for these two nations to combine their respective strengths – India's growing technological ecosystem and the Netherlands' cutting-edge research capabilities – holds the promise of accelerating the development of quantum technologies that will benefit both countries and the global community.

The Report "Unveiling the Indo-Dutch Quantum Frontier: In Search of Opportunities to Integrate Ecosystems", provides a comprehensive overview of the opportunities and challenges that lie ahead. By examining the quantum ecosystems of both nations, the report identifies key areas where collaboration can make a meaningful impact, from research and development to workforce growth and industry partnerships. The insights drawn from leading experts and stakeholders offer a roadmap for how India and the Netherlands can work together to shape the future of quantum science and technology

Within these pages, you will find an in-depth analysis of the Challenges and Opportunities that both nations face, as well as Recommendations for how these challenges can be turned into collaborative successes. Through thoughtful and actionable strategies, this report sets the stage for impactful joint initiatives, including Proof of Concept projects, which will help lay the groundwork for lasting partnerships.

This study represents a significant step toward a shared vision: that India and the Netherlands will not only contribute to the global quantum revolution but will also lead it. The findings here will serve as a guide for fostering long-term collaboration, building on each country's unique strengths to create a vibrant, sustainable quantum ecosystem that advances both nations' ambitions in the field.

DR. V.K. SARASWAT
Chairperson, Governing Board, QETCI

Foreword

The partnership between India and the Netherlands is increasingly been defined by a shared commitment to innovation, technology, and science. We have worked together across multiple high-tech sectors, from semiconductors to artificial intelligence, from biotech to advanced manufacturing. This year we are launching a partnership between the Indian and Dutch government on such key enabling technologies, and thereby we are not only looking at established industries, but also the next big thing. Among these transformative technologies, quantum technology stands out as a game-changer. It holds the potential to revolutionize computing, secure communication, and materials science.

The Netherlands is working actively towards a quantum-powered future. It has the most quantum startups per capita and 10% of European quantum patent applications come from the Netherlands. The Dutch government has taken its place in the driver's seat by funding Quantum Delta, in which DELTA stands for the five academic quantum hubs the Netherlands has: Delft, Eindhoven, Leiden, Twente and Amsterdam. Each hub specializes in a unique area of quantum tech and all have strong international links.

Meanwhile, at the Embassy we have been eagerly watching India's quantum initiatives such as the National Quantum Mission, launched in 2023, which is driving rapid advancements and actively seeking international links to grow the global value chain. India has quickly emerged as a powerhouse of digital innovation, with its thriving startup ecosystem, deep talent pool, and ambitious government policy to stir towards technological self-reliance. The question for us now is how we can connect our ecosystems and work strategically together in a manner that makes both India and the EU flourish.

I am therefore excited to read the results of this report 'Unveiling the Indo-Dutch Quantum Frontier – In search of opportunities to integrate ecosystems'. The report is a result of multiple roundtables, extensive discussions, expert consultations, and joint efforts from industry leaders, academics, and policymakers from both nations. It aims to map the strengths of both quantum ecosystems and also lay out a strategic roadmap for future collaboration—one that includes joint research projects, talent exchange programs, and co-development of quantum-enabled applications. We were happy to learn during this process that Dutch and Indian researchers are already collaborating in this space, exploring quantum cryptography, quantum machine learning, and scalable quantum hardware solutions.

I extend my sincere appreciation to all contributors who made this report possible. As we stand at the cusp of the quantum revolution, let us seize this opportunity to build an Indo-Dutch partnership that will push the boundaries of innovation and deliver a quantum-powered future.

MARISA GERARDS
Ambassador of the Kingdom of the Netherlands to India, Nepal, and Bhutan

Preface

In December 2023, QETCI published a report on the Quantum Value Chain in India, in which we introduced the Quantum Value Chain Framework—a structured methodology to assess the maturity and interconnectedness of components within a quantum ecosystem. At the time, we did not anticipate the extent to which this framework would guide and influence many of our subsequent initiatives.

Soon after, the Innovation team at the Netherlands Embassy in India approached us to explore opportunities for collaboration between the Dutch and Indian quantum ecosystems. This initiative aligned closely with QETCI's mission of fostering international cooperation to accelerate the growth and impact of India's quantum ecosystem. We viewed this collaboration as an exciting opportunity to apply our framework in a cross-national context and derive actionable recommendations for bilateral engagement.

This report is the culmination of a rigorous process involving roundtable discussions, one-on-one interviews, and secondary research. Through this process, we engaged stakeholders from across the quantum landscape—spanning industry, academia, startups, and government—from both India and the Netherlands. Even in the early stages of this engagement, meaningful connections began to form between stakeholders on both sides, demonstrating the tangible potential of intentional and strategic collaboration.

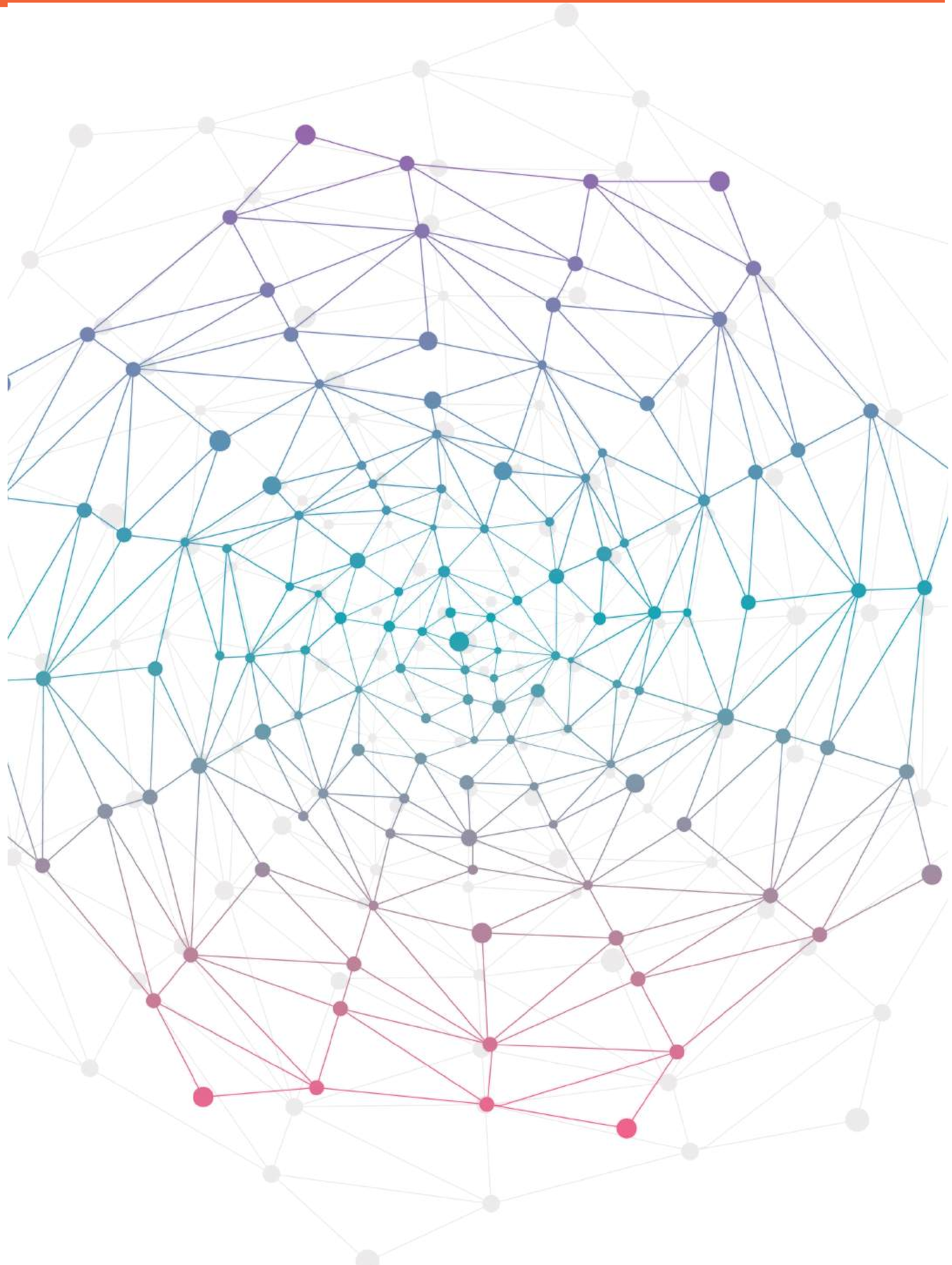
I would like to take this opportunity to express our heartfelt gratitude to the Netherlands Embassy in India, particularly H.E. Marisa Gerards, Ambassador of the Kingdom of the Netherlands to India, Nepal and Bhutan, Dr. Dhoya Snijders, Innovation Counsellor, and Dr. Naman Agarwal, Strategy and Innovation Advisor, for initiating this project and for their continued support throughout its development.

I also wish to thank the QETCI team, especially Mr. Shantanu Sharma, who has played a central role in the preparation of this report, and Ms. Abhishrutha, a former team member whose early groundwork laid the foundation for this effort.

Lastly, my sincere thanks to all the stakeholders from both India and the Netherlands who generously contributed their time, insights, and expertise. Their inputs have been essential in shaping the recommendations and ideas presented here.

It is our hope that this report serves not just as a strategic roadmap, but as a springboard for deeper, more sustained collaboration in quantum technologies between the Netherlands and India.

REENA DAYAL
Founder and CEO, QETCI



Executive Summary

Quantum science and technologies (QST) is poised to transform global industries, from computing and cybersecurity to healthcare and advanced manufacturing. As nations race to establish leadership in this domain, India and the Netherlands are uniquely positioned to collaborate, leveraging their respective strengths to build a more robust, globally competitive quantum ecosystem.

The Netherlands has positioned itself as a European leader in quantum hardware, photonics, and network infrastructure, with robust academic institutions and cutting-edge research. Meanwhile, India, with its ambitious National Quantum Mission (NQM), is rapidly developing expertise in quantum computing, cryptography, and industry applications, supported by a growing startup ecosystem and a strong talent pipeline.

Both India and Netherlands recognize that quantum success is not a solitary pursuit—it demands cross-border collaboration, shared research, and co-development of technologies. This report captures the potential, challenges, and opportunities in forging a deeper Indo-Dutch quantum partnership.

Growing Quantum Ecosystems

Across both nations, quantum research has moved from theoretical exploration to practical implementation, with industry and government playing increasingly active roles.

The Netherlands, backed by more than €615 million in national funding, has established a strong foundation in quantum networking, computing, and sensing. **Anchored by the Quantum Delta NL program and its five innovation hubs**, the ecosystem is driven by key players such as Delft University of Technology, Qblox, QuTech, and a growing number of quantum startups and spin-offs.

The Netherlands is also deeply integrated into European quantum initiatives, participating in the Quantum Flagship, QuantERA, and the European Quantum Industry Consortium (QuIC), solidifying its role as a global quantum hub. Meanwhile, India's National Quantum Mission, with ₹6,000 crore in funding, is focused on building quantum computers, secure quantum communication networks, and industry-ready quantum applications. The initiative has spurred an explosion of research, with four thematic hubs established to advance quantum computing, quantum communication, sensing & metrology, and materials development. The startup landscape has expanded rapidly, with over 45 quantum startups emerging by 2025, driving both indigenous hardware and software innovations.

Despite this momentum, both ecosystems face challenges that hinder their ability to scale independently. India needs stronger hardware and fabrication capabilities, while the Netherlands faces talent shortages and scaling challenges in quantum commercialization. Bridging these gaps through a structured partnership, while utilizing existing infrastructure and funding initiatives, can unlock significant value for both nations.

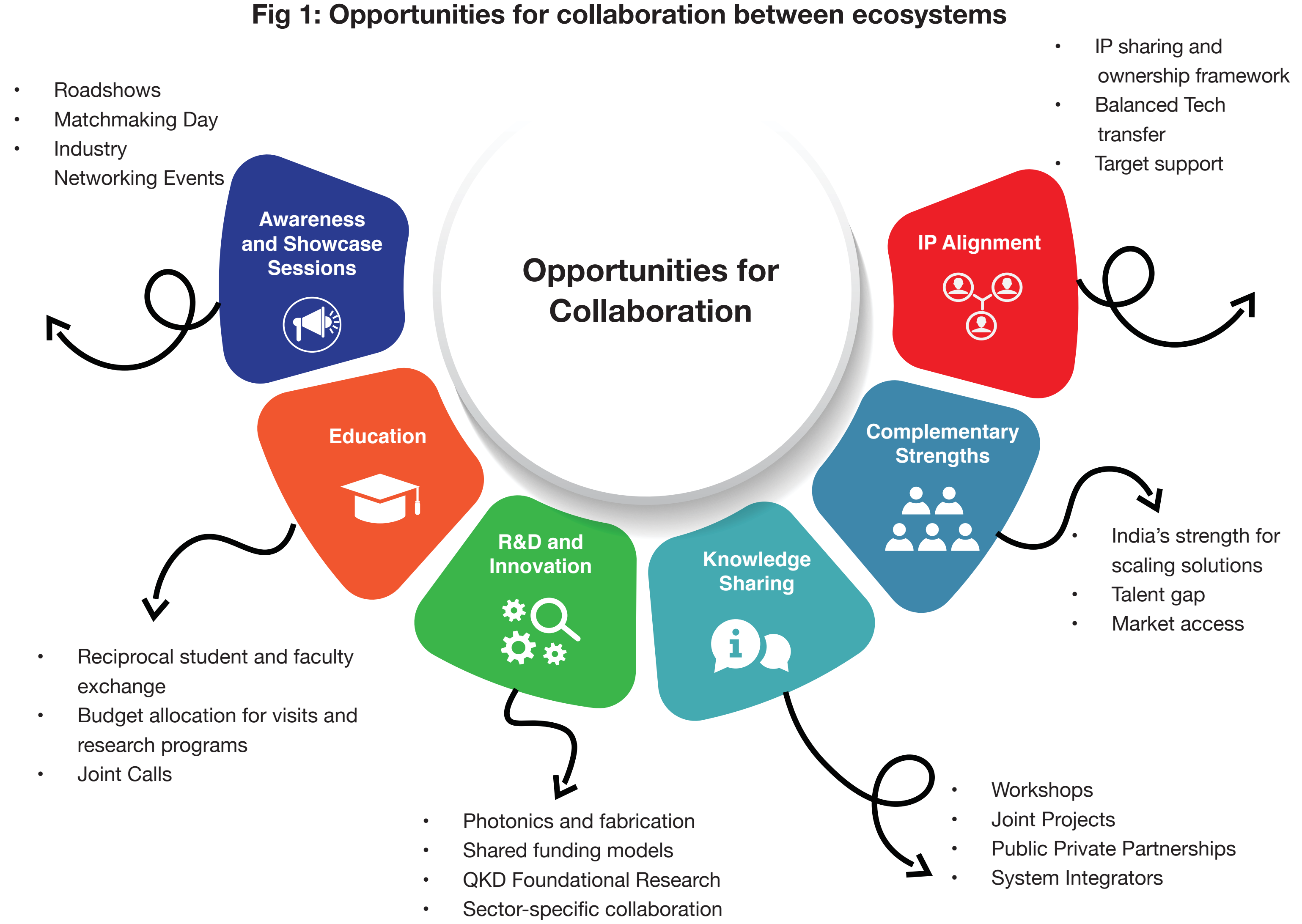
What Is Needed?

One of the biggest challenges to collaboration in QST between India and the Netherlands is the limited connectivity between the two countries' research institutions and industries. When we initiated this study, we discovered that awareness of each other's quantum ecosystems was minimal, and existing connections were sparse. However, as we organized the first roundtable and conducted in-depth interviews, the process itself fostered greater knowledge of the opportunities available in both countries.

As this study progressed, we witnessed multiple stakeholder visits from both sides, which not only facilitated the emergence of new opportunities but also enabled their successful utilization by both countries. This is an indication of the fact that establishing a structured mechanism for continuous engagement in QST will have a transformative impact.

Derived from stakeholder interviews, ecosystem analysis, and national strategies — opportunities for collaboration between India and the Netherlands were identified. These opportunities form the foundation for building long-term partnerships-

Fig 1: Opportunities for collaboration between ecosystems



To formalize identified opportunities and translate them into measurable outcomes, this report proposes five high-priority, targeted interventions across the strategic domains of policy, research, and industry. These interventions build on existing partnerships and can be supported through extensions of current frameworks, while also establishing dedicated tracks for collaboration in quantum. Each recommendation leverages complementary national strengths, offering actionable instruments to accelerate cross-border growth, align efforts with national ecosystem priorities, and enable sustained, high-impact collaboration. To this effect we recommend the following-

1. Bilateral Collaboration in Quantum information Security

Strategic Value: Developing sovereign quantum-secure communication and information security capabilities and prepare critical infrastructure for NISQ transition and the post-quantum era.

India and the Netherlands offer complementary strengths in quantum information security. India's deep talent pool, advanced software engineering, and emerging startups in quantum-resistant algorithms align with Dutch expertise in cryptographic protocol design, enabling joint development of industry-ready post-quantum cryptography (PQC) solutions. Indian system integrators and IT consultancies can support Dutch firms—particularly SMEs—with scalable, affordable, and agile quantum-secure solutions. Furthermore, co-development of quantum network components such as repeaters and memory modules can benefit from Dutch strengths in photonics and fabrication, and India's capabilities in system integration, scalable manufacturing, and engineering talent.

Key Initiatives:

- Leverage Indian IT expertise to support Dutch SMEs through system integration and consulting for PQC migration.
- Facilitate sector-specific collaboration to develop standards, regulations, and policies for PQC migration.
- Develop industry-ready PQC solutions tailored to the needs of SMEs.
- Launch a pilot bilateral quantum communication network.
- Jointly develop low-cost enabling technologies for quantum networks, including quantum repeaters, memory modules, and cryogenic systems.
- Collaborate on global standardization initiatives through bodies such as ISO/IEC, IEEE, and ITU.
- Coordinate participation in international forums, including GFCE, UN, and OECD.
- Conduct sector-specific awareness sessions on quantum information security.

2. Collaboration in Key Sectors

Strategic Value: Focus on high-impact sectors to accelerate commercialization and policy alignment by translating quantum research and complementary strengths into tangible economic and societal outcomes.

Key Sectors and Potential Streams for Collaboration:

- **Telecommunications:** Joint development of quantum encryption solutions for 5G/6G networks, PQC-QKD protocols, and secure infrastructure, leveraging Dutch photonics capabilities and Indian system integration expertise and massive telecom sector. This collaboration can enhance future-ready telecom security architecture.
- **Banking, Financial Services, and Insurance:** Collaborate on quantum-enhanced fraud detection, portfolio optimization, risk modelling, and anti-money laundering mechanisms. Establish joint regulatory sandboxes to test PQC and QKD protocols and quantum-secure financial transactions, ensuring interoperability with legacy systems and contributing to global standards. This will support secure, interoperable financial infrastructure and contribute to public trust and financial integrity in the quantum era.
- **Manufacturing:** Co-develop quantum sensing, simulation, and optimization tools to enhance manufacturing through predictive maintenance, advanced materials, and high-precision quality control. Joint efforts in quantum hardware, photonic components, and fabrication infrastructure will accelerate commercialization and scale. Leveraging India's manufacturing base and the Netherlands' strengths in materials science can foster a resilient, integrated quantum supply chain with strong economic and strategic value.
- **Aerospace Technologies:**
  Building on existing deep Indo-Dutch space sector partnerships, extend collaboration in quantum satellite payloads, satellite-based QKD, and quantum-enhanced navigation systems, Joint research in quantum sensing—such as atomic clocks, gravimeters, and inertial units—can enhance secure communications, navigation, and earth observation and climate monitoring. These efforts will enhance public safety, improve disaster management, and support critical infrastructure, and enable sustainable resource planning.
- **Biotechnology, Pharmaceutical, and Healthcare:**
  Co-develop quantum-enhanced diagnostics, imaging, drug-discovery, and biomedical tools by leveraging India's clinical infrastructure and the Netherlands' strength in medical innovation. Streamlined regulation and joint pilot programs will accelerate clinical integration. These innovations can enable preemptive detection, personalized treatment, and broader access to quality healthcare.

3. Dedicated Innovation Hub

Strategic Value: Anchor long-term collaboration through dedicated physical and virtual infrastructures.

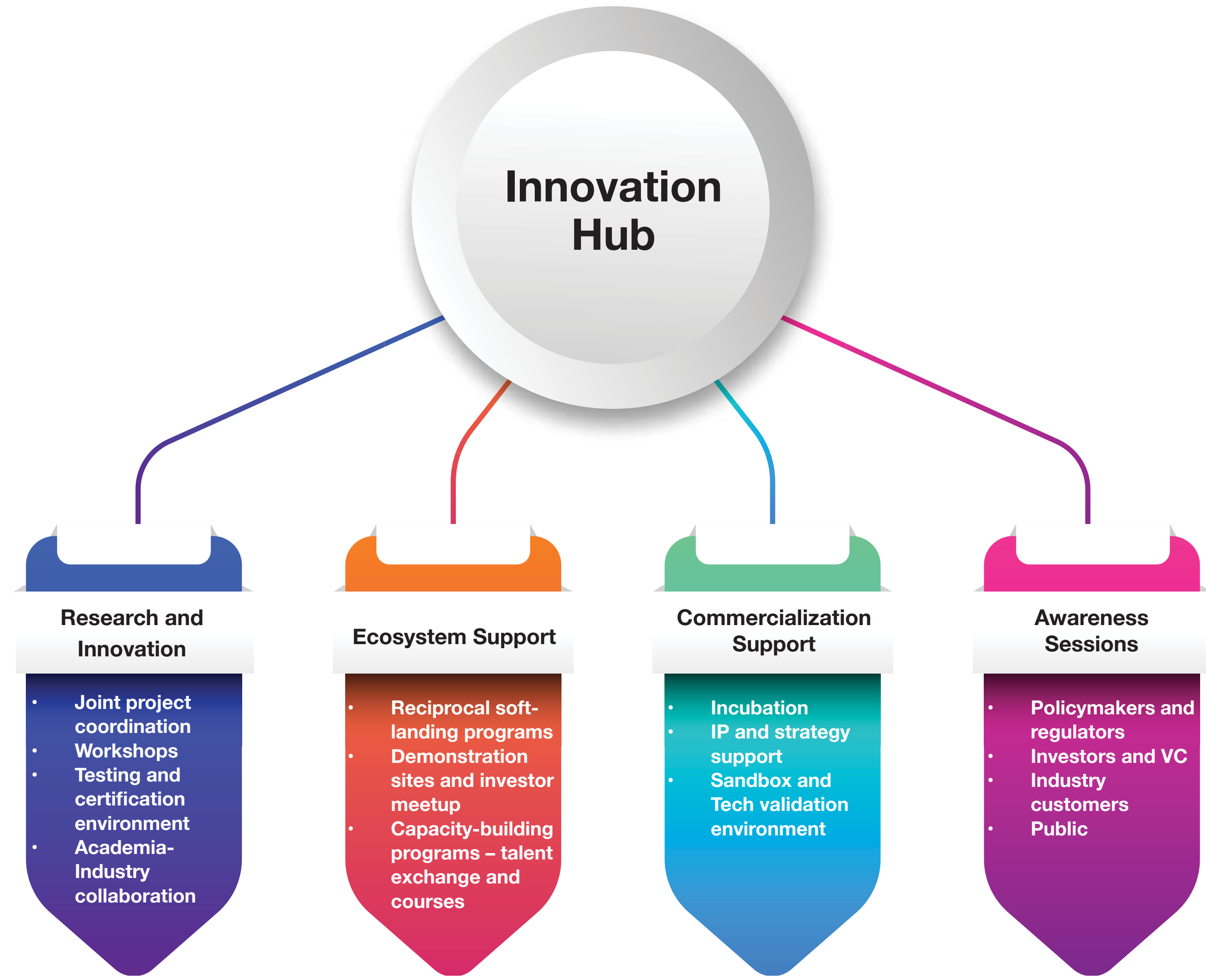
India and the Netherlands should establish bilateral quantum innovation hubs to catalyze co-development, testing, and commercialization of quantum technologies. Proposed hubs should consist of virtual and physical bridges, connecting existing testbeds, cloud platforms, and startups to drive joint innovation and industry engagement. Public–private partnership (PPP) models should co-finance hub operations, ensuring long-term sustainability and industry engagement. Organizations like RVO and DST can contribute to seed grants for the same.

Dedicated innovation hubs would serve multiple functions-

- Act as Centres of Excellence for quantum subdomains
- Support joint research, startup incubation, and policy coordination.
- Facilitate reciprocal soft-landing programs for industry.
- Host capacity-building programs, workshops, and investor roundtables.
- Organize awareness programs for policymakers, regulators, and industry leaders.
- Demonstration sites to showcase real-world applications.
- Quantum testbeds and sandbox to validate technologies prior to commercialization.
- Offer legal and technical expertise to navigate joint IP ownership, patents, licensing, and commercialization strategies.

The dedicated hubs can provide structured workforce mobility and talent development programs. The hubs should serve as training grounds for quantum professionals, hosting short-term and long-term exchange programs, industry immersion sessions, and technical certification courses.

Fig 2: Innovation Hub



4. Testing and Certification

Strategic Value: Lower barriers to market entry through shared validation and certification frameworks and accelerate commercialization timelines, build global investor confidence, and enable the development of trusted quantum products.

India's software testing and the Netherlands' hardware certification capabilities are ideal complements. Joint testing labs with mutual recognition frameworks can validate QST components faster and cheaper. Shared access to facilities, standardization with international compliance regimes, and co-developed benchmarking protocols will reduce commercialization barriers and improve investor confidence.

Key Initiatives:

- Certification protocols for QKD, QRNG, and quantum sensors aligned with ISO, IEEE, FIPS, CC.
- Cross-border performance benchmarking and test data sharing.
- Capacity-building programs for engineers and technicians in standards testing.
- Certification and interoperability testing for

5. Inter-Governmental Coordination and Alignment

Strategic Value: While innovation hubs and grassroots initiatives can drive bottom-up change, top-down government-to-government coordination is required to address systemic challenges.

Despite the strong potential for India–Netherlands collaboration in quantum science and technology, progress is hindered by legal, regulatory, and administrative barriers—particularly acute in the quantum domain, where national security, commercialization, and global competitiveness intersect. Issues such as IP protection, export controls, and regulatory misalignments disproportionately affect startups and research institutions. To address this, a structured approach across **three strategic streams** is recommended **supported by dedicated working groups/task force** and regular stakeholder consultations to ensure sustained alignment and progress-

5.1. Access to Research Infrastructure: Procurement, Customs, and Investment

Potential Stakeholders:

- From India – DST, MeitY (including C-DAC), MCI, MEA, NSCS, SETS, TEC, C-DOT, Representatives from T-Hubs
- From Netherlands – OCW, RVO, RDI, Ministry of Foreign Affairs, NEN, AIVD, CWI, Representatives from Quantum Delta Hubs

Focus Area:

- Establish "quantum research corridor" to fast-track customs clearance, export licensing, and procurement of quantum systems and components, specifically for joint India–Netherlands R&D projects.
- Initiate structured bilateral dialogue to identify critical quantum components, share best practices in IP protection, and prevent regulatory misalignments.
- Reduce repair and maintenance costs for quantum systems through joint initiatives, lowering supply chain dependencies and improving affordability.
- Streamline and mutually recognize licensing, certification, and testing standards,
- Strengthen strategic trade and supply chain integration to support manufacturing and commercialization, especially for undercapitalized quantum startups.

5.2. Regulatory, Standards, and Policy Alignment

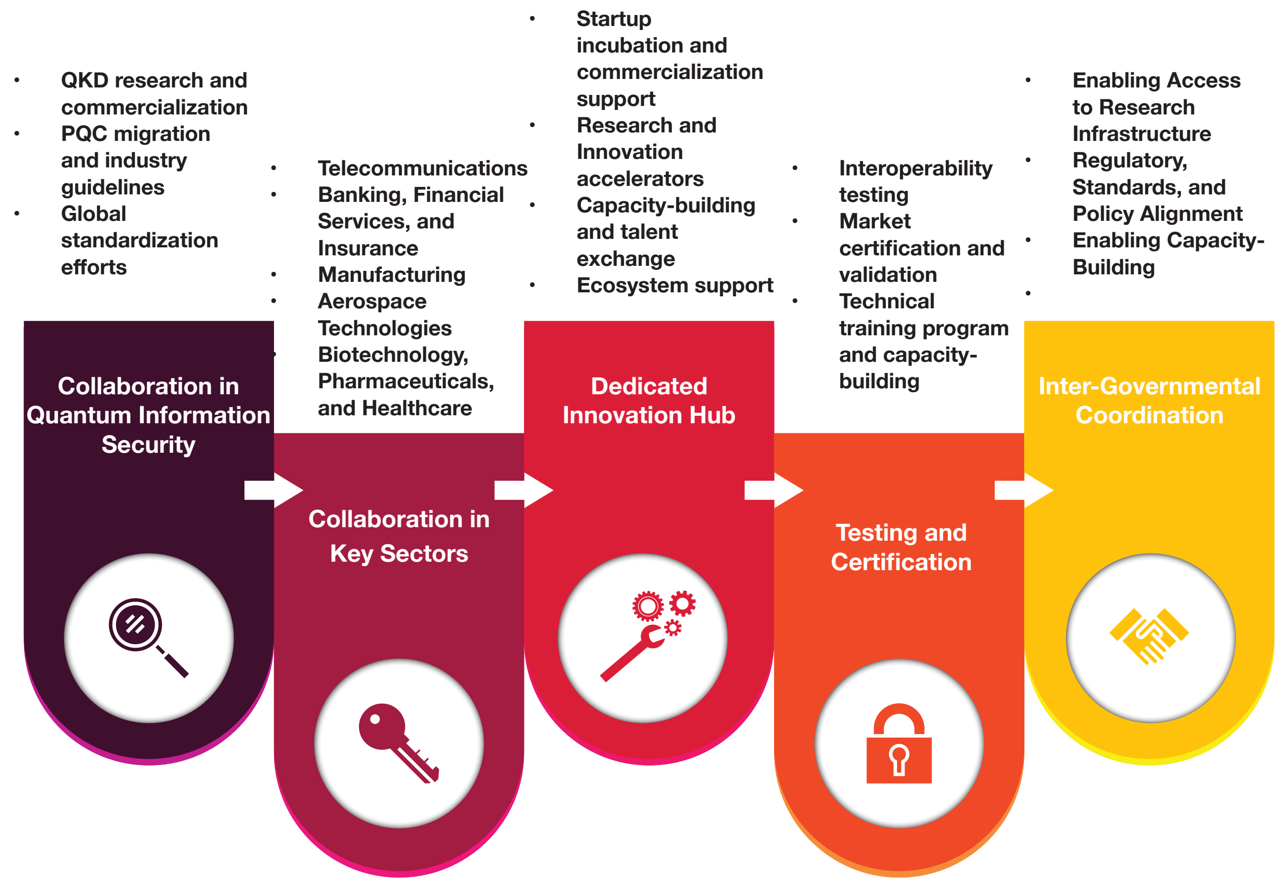
Potential Stakeholders:

- From India – DST, MeitY (including CERT-In and C-DAC), TEC, C-DoT, SETS, DSCI, BIS, NCIIPC, Representatives from T-Hubs
- From the Netherlands –NEN, RVO, RDI, TNO, NCSC, Dutch Data Protection Authority, Representatives from Quantum Delta Hubs

Focus Area:

- Track and evaluate national quantum strategies to identify areas of convergence, synergy, and ecosystem coordination.
- Drive sector-specific initiatives including joint standard-setting, regulatory alignment, expert exchanges, and capacity-building through training and workshops.
- Establish a bilateral dialogue mechanism involving science attachés, trade diplomats, legal experts, and quantum policymakers to align regulatory frameworks, national strategies, and standardization efforts.
- Facilitate sustained legal and policy discourse to reduce friction in collaboration and enhance preparedness for multilateral quantum governance.
- Pursue joint engagement with global standard-setting bodies (e.g., ITU, ISO/IEC, ETSI) to influence international quantum standards and reflect national priorities.
- Embed bilateral regulatory cooperation within broader multilateral frameworks such as the EU–India Trade and Technology Council (TTC) to enhance global impact.

Fig 3: Strategic Recommendations and Investment Prioritization



5.3. Enabling Capacity-building for Quantum Ecosystems

Focus Area:

- Streamline talent mobility via coordinated mechanisms for researcher exchanges, visiting faculty, startup co-location, and supportive visa, IP, and institutional processes.
- Design innovation programs and joint funding mechanisms that prioritize use-case-driven research and drive sector-specific collaborations.
- Reduce administrative and legal barriers by creating dedicated liaison services or consulting support for startups and academic institutions navigating complex cross-border requirements.
- Organize regular bilateral innovation and trade missions through embassies and innovation agencies to deepen stakeholder engagement and ecosystem trust.
- Identify and formalize academia, industry and government partnerships and commitments through agreements and Memoranda of Understanding (MoUs) to facilitate long-term collaboration and knowledge exchange.
- Policy foresight on quantum ethics, security, and standards.

QST sits at the confluence of scientific ambition, geopolitical transformation, and societal need. QST demands an approach that is not only innovative, but also inclusive, ethical, and globally collaborative. In this context, the India–Netherlands partnership emerges as a vital bridge—linking diverse perspectives, complementary strengths, and a shared commitment to advancing technology for the common good.

Technology should be a bridge—not a barrier. It should foster cooperation, not division. In this spirit, quantum collaboration must be underpinned by shared principles: openness, transparency, freedom of inquiry, equitable competition, and strong intellectual property protections. These values will ensure that quantum progress remains rigorous, inclusive, and aligned with democratic ideals.

Realizing this vision also requires confronting structural challenges. The success of Indo-Dutch Partnership in QST depends on immediate action: dedicated funding, structured industry engagement, academic partnerships, and regulatory alignment. If implemented effectively, this partnership could set a global benchmark for cross-border quantum collaboration, paving the way for breakthroughs that benefit not just two nations, but the world at large.

Abbreviations

ABBREVIATION	DEFINITION
AICTE	All India Council for Technical Education
AICCTP	Australia-India Cyber and Critical Technology Partnership
AIVD	General Intelligence and Security Service (Netherlands)
BIS	Bureau of Indian Standards
CC	Common Criteria
CERT-In	Indian Computer Emergency Response Team
CQE	Chicago Quantum Exchange
C-DAC	Centre for Development of Advanced Computing (India)
C-DoT	Centre for Development of Telematics (India)
CWI	Center for Mathematics and Computer Science (Netherlands)
DSCI	Data Security Council of India
DoT	Department of Telecommunications (India)
DST	Department of Science and Technology (India)
EU-India TTC	European Union–India Trade & Technology Council
ETSI	European Telecommunications Standards Institute
FIPS	Federal Information Processing Standards
IEEE	Institute of Electrical and Electronics Engineers
IISc	Indian Institute of Science
IIIT	Indian Institute of Information Technology
IISER	Indian Institute of Science Education and Research
IIT	Indian Institute of Technology
IP	Intellectual Property
ISO	International Organization for Standardization
ISM	India Semiconductor Mission
MEA	Ministry of External Affairs (India)
MeitY	Ministry of Electronics and Information Technology (India)
MCI	Medical Council of India
MoU	Memorandum of Understanding
NAQT	National Agenda for Quantum Technology (Netherlands)
NCIIPC	National Critical Information Infrastructure Protection Centre (India)
NCSC	National Cyber Security Centre (Netherlands)
NEN	Netherlands Standardization Institute
NM-ICPS	National Mission on Interdisciplinary Cyber-Physical Systems (India)
NQM / NMQTA	National Quantum Mission (India)
NM-QTA	National Mission on Quantum Technologies and Applications (India)
NSCS	National Security Council Secretariat (India)

ABBREVIATION	DEFINITION
NSA	National Security Agency
NSM	National Supercomputing Mission (India)
NTS	National Technology Strategy (Netherlands)
NWO	Dutch Research Council
OCW	Ministry of Education, Culture and Science (Netherlands)
PoC	Proof of Concept
PQC	Post-Quantum Cryptography
PSA	Principal Scientific Adviser (India)
QCoE	Quantum Center of Excellence
QDNL	Quantum Delta Netherlands
QED-C	Quantum Economic Development Consortium
QETCI	Quantum Ecosystems Technology Council of India
QKD	Quantum Key Distribution
QRNG	Quantum Random Number Generator
QST	Quantum Science and Technology
QuEST	Quantum Enabled Science and Technology
QT/e	Quantum Technology Eindhoven (TU Eindhoven)
QuSoft	Quantum Software Consortium (University of Amsterdam)
QuTech	Quantum Technology institute (TU Delft & TNO)
R&D	Research and Development
RDI	Netherlands Enterprise Agency for Innovation
RRI	Raman Research Institute (India)
RVO	Netherlands Enterprise Agency
SETS	Society for Electronic Transactions and Security (India)
SIPP	Scheme for Facilitating Start-Ups Intellectual Property Protection
TCS	Tata Consultancy Services
TEC	Telecommunication Engineering Center (India)
TIH	Technology Innovation Hub
TNO	Netherlands Organisation for Applied Scientific Research
TSI	UK-India Technology Security Initiative
TU Delft	Delft University of Technology
VC	Venture Capital

I Introduction

Quantum Science and Technologies (QST), rooted in the principles of quantum mechanics, have the potential to revolutionize computing, communication, and sensing. These advancements are poised to transform industries by driving innovation across sectors such as cybersecurity, healthcare, finance, and advanced manufacturing, enabling groundbreaking progress and redefining the boundaries of technological capabilities.

Recognizing the immense potential of QST to shape the future of technology and economics, countries around the world have sought to establish themselves as leaders in this field.

India and the Netherlands both have National Initiatives in Quantum. There is an opportunity for both nations to collaborate in this area, exemplifying forward-thinking partnerships, designed to leverage the strengths of both nations.

The study, titled “Unveiling the Indo-Dutch Quantum Frontier: In Search of Opportunities to Integrate Ecosystems,” was conducted by the Quantum Ecosystems Technology Council of India (QETCI) and the Embassy of the Kingdom of the Netherlands in India. This study formed part of a broader initiative aimed at strengthening and integrating the quantum ecosystems of both countries, fostering cross-border innovation and collaboration across research, industry, academia, and startups.

The study identifies areas for collaboration across various domains of the quantum value chain, creating new opportunities for joint research, innovation, and workforce development. By capturing insights from key stakeholders, this report outlines targeted recommendations for future collaborative projects and Proof of Concept (PoC) initiatives. These insights also help address challenges, identify opportunities, and establish best practices to advance quantum science and technology collaboration between India and the Netherlands.

The objectives of this project were:

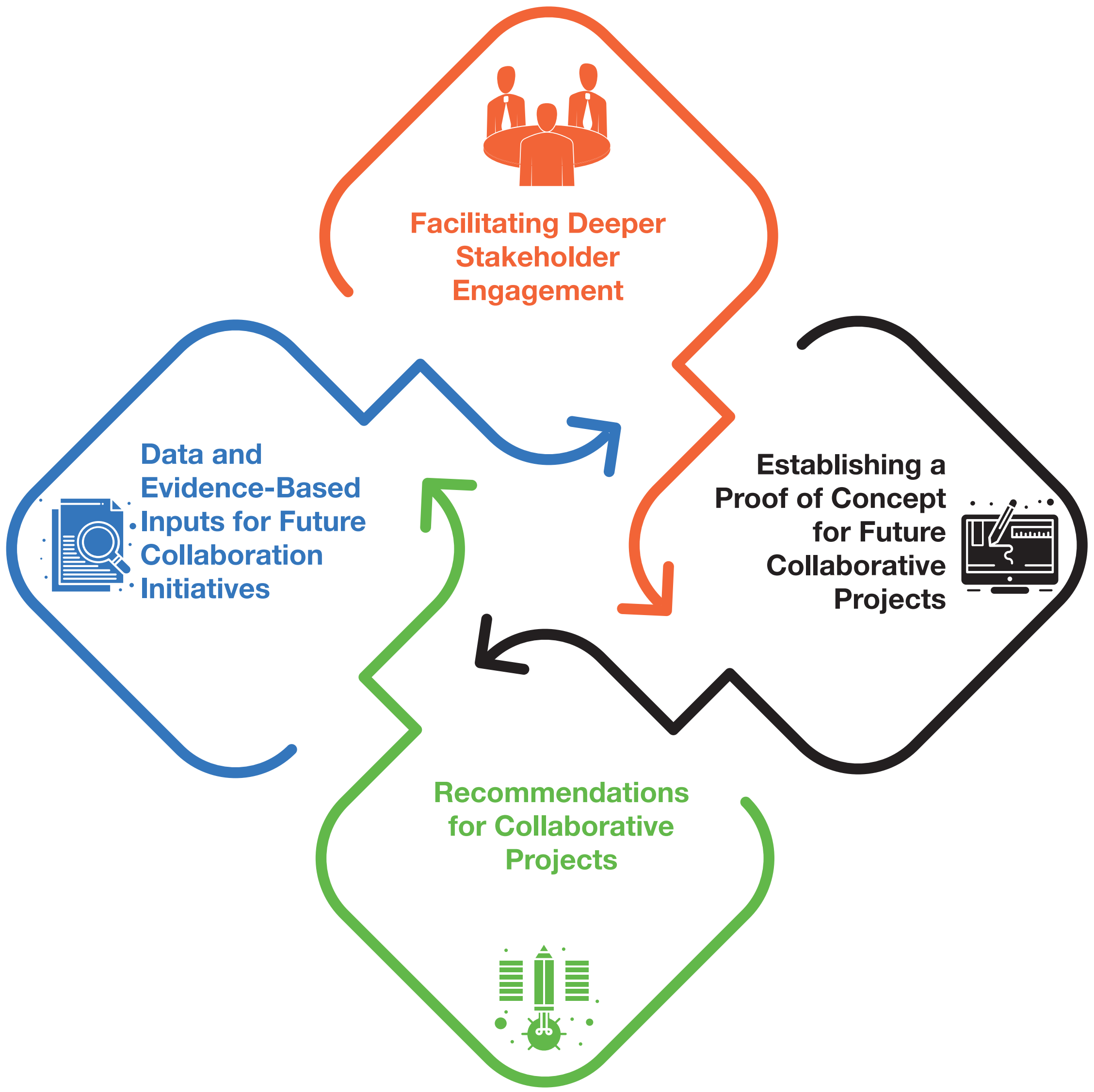
- **Facilitating Deeper Stakeholder Engagement:**
  The initiative convened key stakeholders from India and the Netherlands to explore opportunities for deeper collaboration. These stakeholders included representatives from industry, academia, startups, and the investor community. By fostering connections and enabling the discovery of capabilities, the project aimed to create a platform for long-term, impactful partnerships.

- **Data and Evidence-Based Inputs for Future Collaboration Initiatives:**
  A comprehensive Value Chain Analysis was conducted to examine the bilateral opportunities in Quantum between India and the Netherlands. This report serves as a data-driven resource, identifying areas with the highest potential and offers recommendations to guide future initiatives.

- **Curating Recommendations for Collaborative Projects:**
  Based on the findings, a set of curated recommendations for the next phase of large, high-impact collaborative projects between India and the Netherlands was prepared. These recommendations focus on leveraging the strengths of both countries to address challenges and capitalize on emerging opportunities in quantum technology.

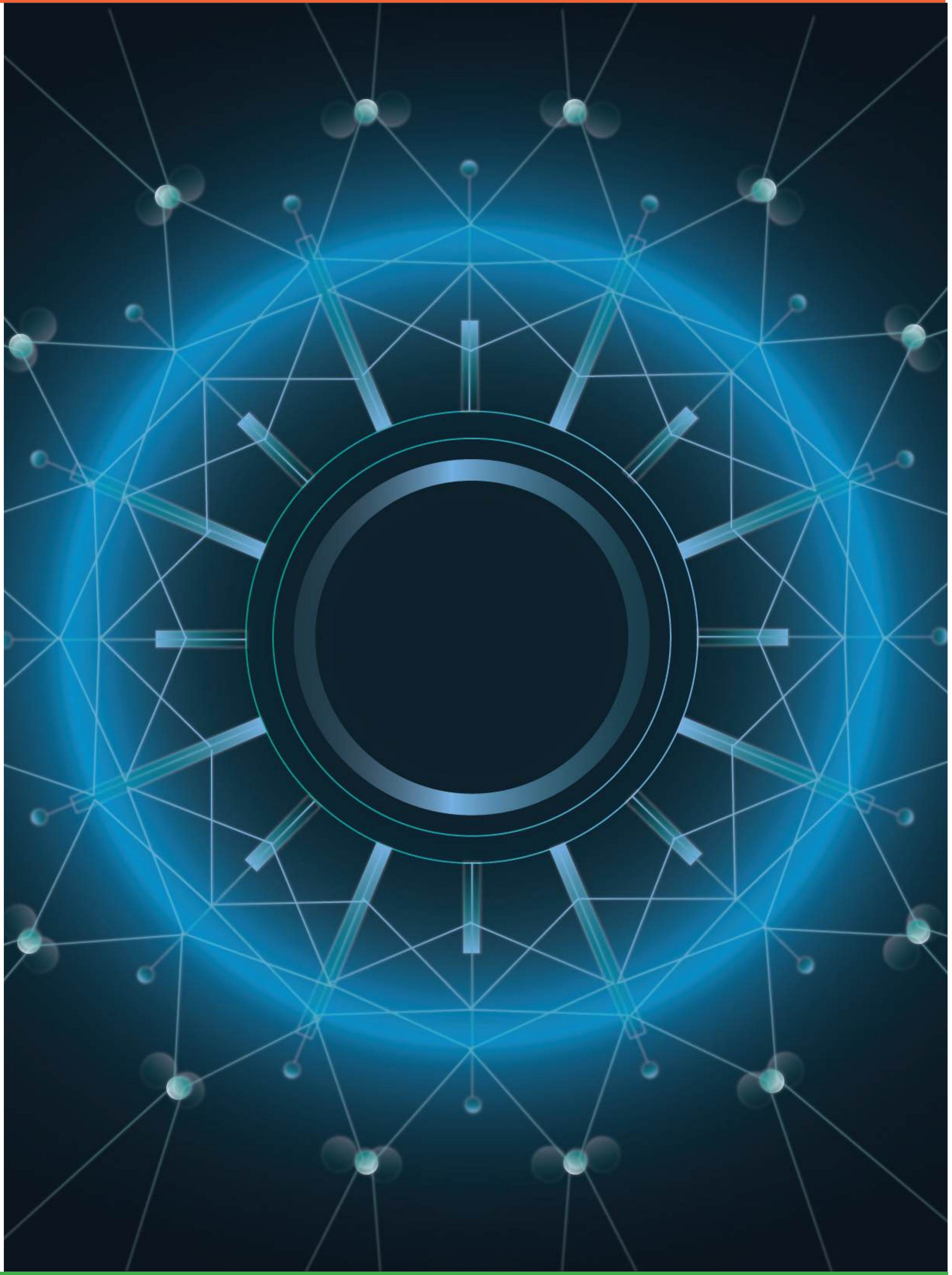
- **Establishing a Proof of Concept for Future Collaborative Projects:**
  The initiative serves as a Proof of Concept to test and refine strategies for international collaboration. By identifying best practices, challenges, opportunities, and potential pitfalls, the project helps the Netherlands Innovation Network Team and QETCI understand the dynamics of cross-border collaboration. The insights gained will inform future projects and contributes to the development of a sustainable framework for long-term partnerships.

This project represents an important step towards strengthening the quantum technology collaboration between India and the Netherlands. Through deeper stakeholder engagement, data-driven analysis, and curated recommendations, the initiative fosters innovation and builds a foundation for sustainable, impactful partnerships. By serving as a proof of concept, the project provided valuable lessons and best practices for future collaboration, contributing to the aim of both countries to be well-positioned to lead the quantum technology ecosystem.



Scope of the report

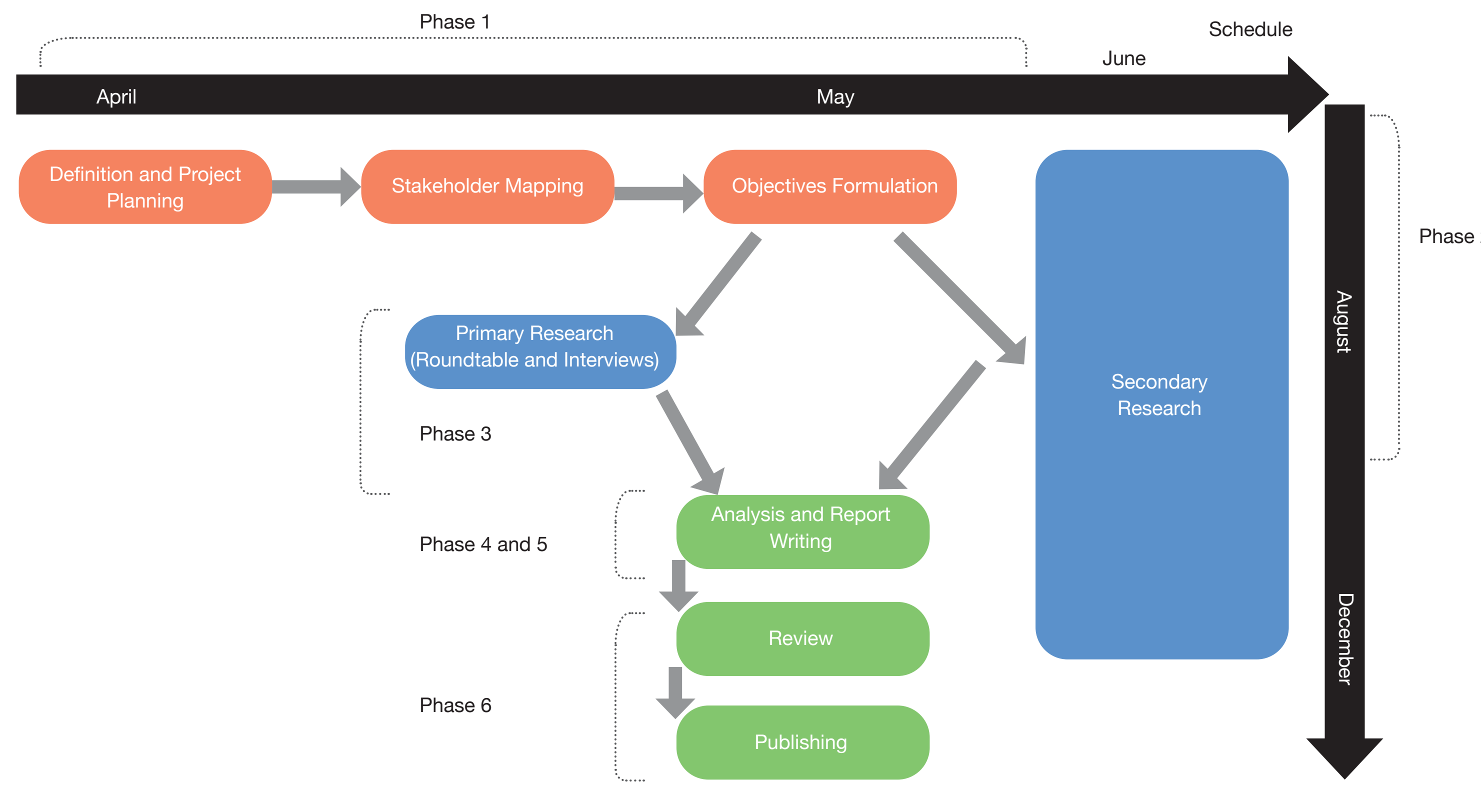
Interviews and data collection for this report were conducted during the second and third quarter of 2024–25. While the analysis includes a broad set of stakeholders, it does not include stakeholders associated with defense and national security-related domains.



2 Research Methodology

The research methodology for the "Unveiling the Indo-Dutch Quantum Frontier" study were designed to provide a comprehensive, data-driven, and multi-dimensional understanding of the quantum technology ecosystems in India and the Netherlands. The methodology employed a combination of desk research, stakeholder engagement, qualitative and quantitative analysis, and collaborative discussions to identify synergies, challenges, and actionable recommendations. Below is an elaboration on the phases and processes followed throughout the project.

Fig 4: Research Phase Timeline



Phase 1: Planning and Objective Formulation

The first phase involved establishing the objectives of the report, and identifying categorizing and mapping the relevant stakeholders, defining the various stages of the research, and setting project timelines.

Phase 2: Desk Research and Preliminary Analysis

The second phase established the foundation for the study through extensive secondary research, enabling the mapping of the existing quantum technology landscape in both India and the Netherlands. The details for phase 2 are as follows:

Objective: To gain a thorough understanding of the current state of the quantum ecosystems in India and the Netherlands, along with a deeper insight into the policies, players, and market conditions that shape these ecosystems.

Research Sources: The desk research involved reviewing:

- Government policies, white papers, and strategic documents related to quantum technology in India and the Netherlands, providing insights into national priorities and long-term objectives.
- Published academic papers, market reports, and case studies that offered empirical data, trend analysis, and practical applications within the quantum sector.
- Reports from industry bodies and international quantum technology forums, which served as benchmarks for comparing and contrasting the development trajectories of both ecosystems.

Deliverables:

- **Mapping the Landscape:** Identified key stakeholders, such as startups, academic institutions, government research centers, and private industry leaders, as well as investors engaged in quantum technology development.
- **Policy Analysis:** Analyzed the governmental initiatives and funding programs in both countries, detailing their impact on quantum R&D, commercialization efforts, and workforce development.
- **SWOT Analysis**: Conducted a preliminary SWOT analysis to highlight the strengths, weaknesses, opportunities, and threats in each country's quantum landscape, providing context for identifying collaboration opportunities.

Phase 3: Stakeholder Engagement and Data Collection

Stakeholder engagement was central to this study, allowing for a more nuanced understanding of collaboration opportunities, challenges, and perspectives from various participants in the quantum ecosystem in both countries. This phase focused on gathering insights directly from key stakeholders through organized activities.

3.1 Roundtable Discussion:

- A roundtable discussion was organized , offering a platform for high-level exchanges among key stakeholders from academia, industry, startups, and government from both countries.This focused on Fostering collaboration between research institutes and academic institutions. Discussions centered around joint research programs, sharing of scientific resources, and potential collaborations between Dutch and Indian universities and research centers.
- Industry and startup collaboration by examining possible synergies across the quantum value chain, including hardware, software, and applications. Topics included cross-border innovation, commercialization strategies, and potential partnerships.

3.2 Surveys and Interviews:

- Customized surveys and one-on-one interviews were employed to gather insights from a wide range of stakeholders. The surveys were categorized by role (e.g., academia, industry, government) and provided structured data, while interviews offered more in-depth, qualitative insights.
- **Survey Development:** Surveys were designed to address key areas, such as collaboration potential, current challenges in international partnerships, technical needs, and policy barriers.
- **Targeted Interviews:** More than 10 virtual interviews were conducted with strategic leaders from both countries. The interviews offered a more nuanced view of individual priorities, expectations, and insights into cross-border collaboration challenges.This facilitated the exploration of opportunities for long-term strategic partnerships, policy alignment, and investment opportunities.

3.3 Outcomes:

- Stakeholders shared their perspectives on the level of readiness for collaboration, the gaps in existing partnerships, and the technical or commercial areas where collaboration could have the highest impact.
- Stakeholder mapping provided clear identification of the major players and emerging startups within the quantum ecosystem in both countries.

Phase 4: Data Analysis and Synthesis

The data collected through research, roundtable discussions, surveys, and interviews were analyzed systematically to identify trends, challenges, and opportunities for collaboration.

4.1 Quantitative Analysis:

Survey data was analyzed using statistical tools to identify trends and patterns. The quantitative approach allowed for:

- **Understanding the stakeholde**r mapping. Identifying technical areas, business areas and policy areas that were of topmost concern for them.
- **Trend Identification**: Highlighting sectors with the highest potential for collaboration based on stakeholder feedback and market data.
- **Prioritization of Investment Opportunities:** Based on stakeholders' responses, opportunities were prioritized to help Dutch stakeholders navigate the Indian quantum technology landscape.

4.2 Qualitative Analysis:

The qualitative data from interviews and roundtable discussions was analyzed to understand the deeper concerns, opportunities, and sentiments of stakeholders. This analysis involved:

- **Thematic Categorization:** Key themes from the interviews and discussions were identified, such as the need for joint R&D, knowledge-sharing, workforce development, and legal/regulatory barriers.
- **Insight Synthesis:** The combination of both qualitative and quantitative findings helped in creating a more holistic view of the opportunities and challenges, allowing the study to provide well-rounded recommendations.

4.3 Gap and Risk Analysis:

A critical part of this phase was conducting a Gap Analysis to understand where the current efforts in both ecosystems were lacking and where synergies could be better exploited. In addition, a Risk Analysis identified potential hurdles (e.g., regulatory issues, funding gaps, skill shortages) that could impede collaboration efforts.

Phase 5: Report Development and Recommendations

Following the analysis, the findings were synthesized into a comprehensive final report that included actionable recommendations for stakeholders in both countries.

Key Report Elements :

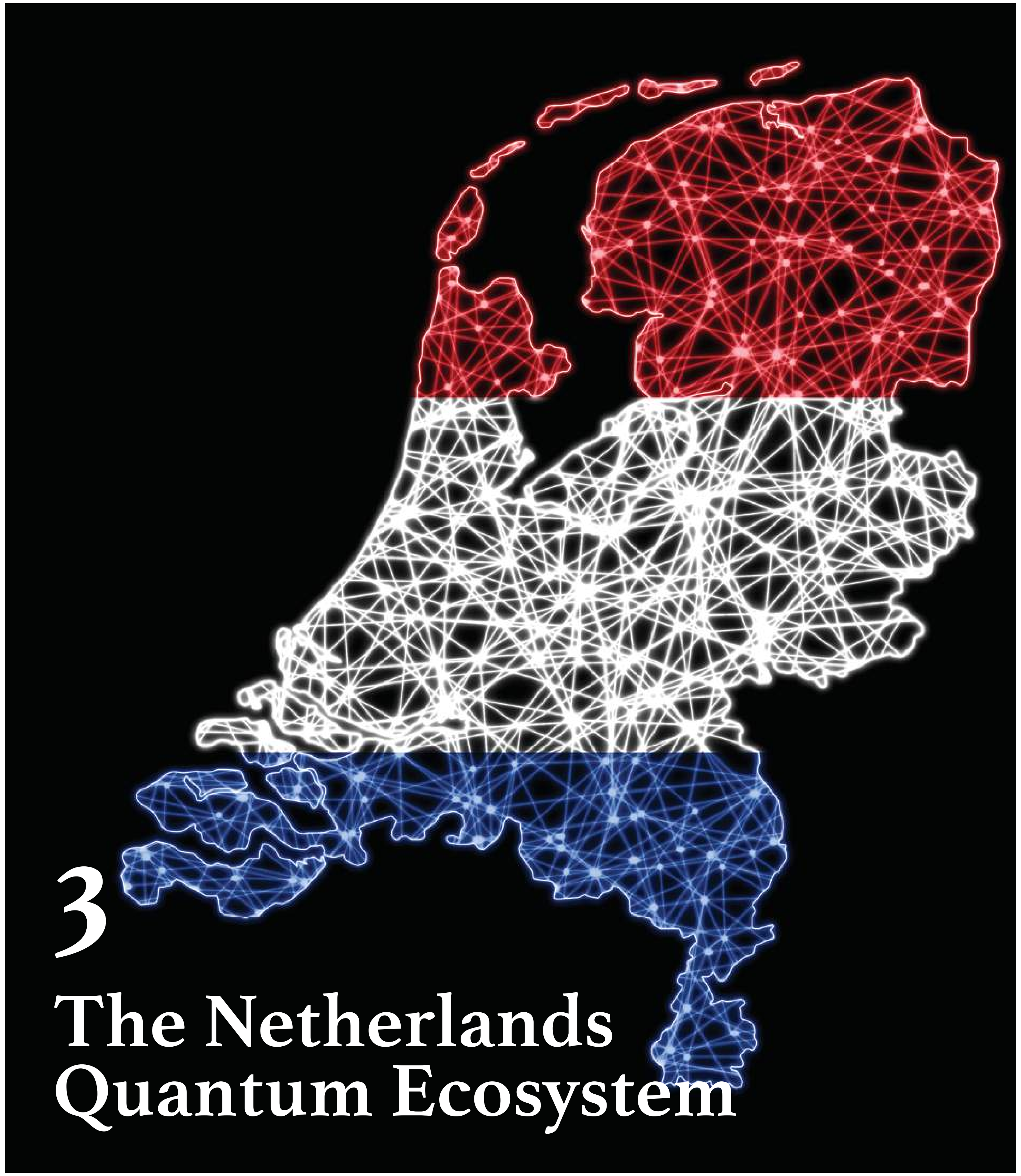
- **Executive Summary:** A three-page management summary of key findings and recommendations.
- **Opportunities for Collaboration:** Detailed opportunities for joint research and development, innovation, and knowledge-sharing.
- **Legal and Regulatory Insights:** Analysis of existing legal frameworks and policy environments in both countries, highlighting bothopportunities and barriers for collaboration.
- **Investment Prioritization:** A clear, prioritized list of investment areas with the highest potential for impactful collaboration over the next three years.
- **Strategic Recommendations:** Tailored recommendations for Dutch stakeholders on how best to engage with the Indian quantum technology ecosystem.

Phase 6: Review, Finalization, and Presentation

The final phase involved consolidating the findings and ensuring that key stakeholders had a chance to review the recommendations before the official release of the report.

- A presentation and review with some key stakeholders. This was done to collect feedback and inputs for the report structure as well as any additional analysis that needed to be done, or analysis that was not relevant to the report.
- Publication. Report was published and is available as a soft copy as well as printed copies.

This multi-phased approach and robust methodology ensured that the study was thorough, inclusive, and aligned with the goals of fostering deeper collaboration between India and the Netherlands in the quantum technology sector. By combining data-driven insights, stakeholder engagement, and practical recommendations, the study provided a clear roadmap for future Indo-Dutch collaboration in quantum technology.



3 The Netherlands Quantum Ecosystem

1. Evolution of the Ecosystem: Towards a National Strategy

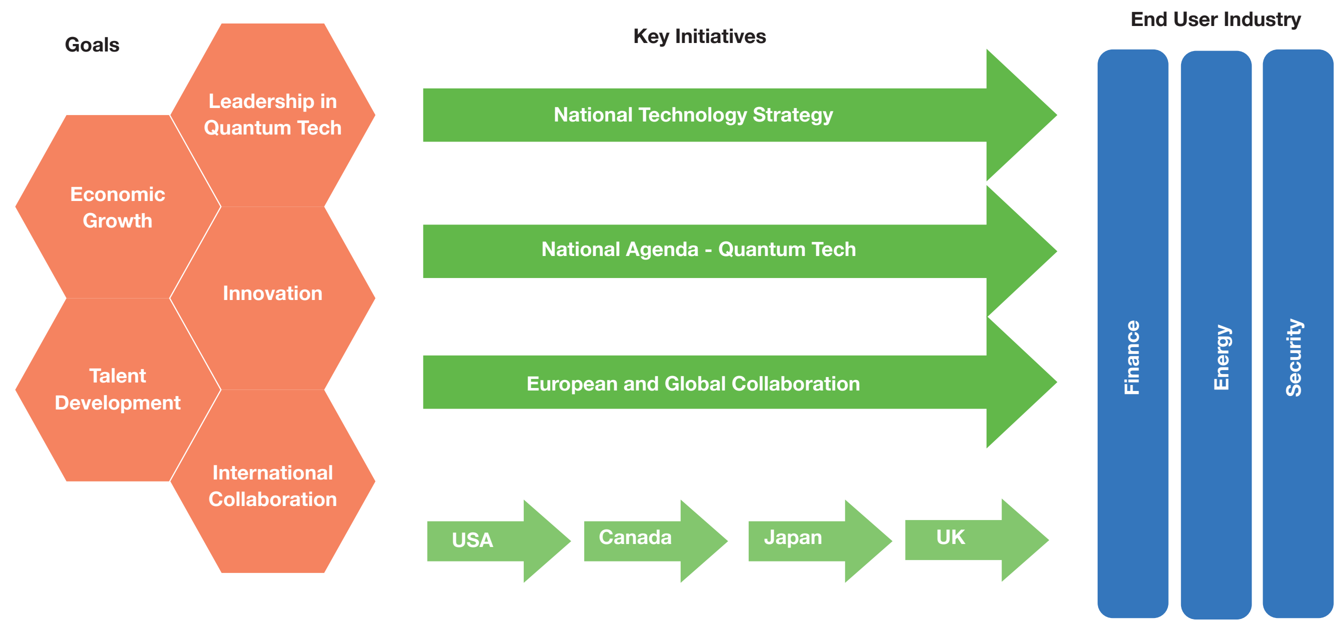
The Netherlands has steadily developed a coherent, long-term strategy to harness quantum technologies, building on a strong foundation of research and collaboration across academia, industry, and government. This multifaceted approach aims to position the country as a global leader by aligning scientific excellence with ecosystem growth and innovation.

The Netherlands' quantum ecosystem (see figure 5) had been steadily evolving through research initiatives and collaborations. The launch of the National Agenda Quantum Technology (NAQT) in 2019 marked a significant step in consolidating and accelerating prior research and collaborative efforts across the country's academic, industrial, and policy communities. The NAQT outlined four key action lines-

1. **Quantum research and innovation**
2. **Ecosystem development**
3. **Human capital growth**
4. **Public dialogue on the societal impact of quantum technologies.**

The agenda strengthened research outcomes while fostering cross-disciplinary collaboration and laying the groundwork for large-scale technological integration

Fig 5: Netherlands Quantum Ecosystem

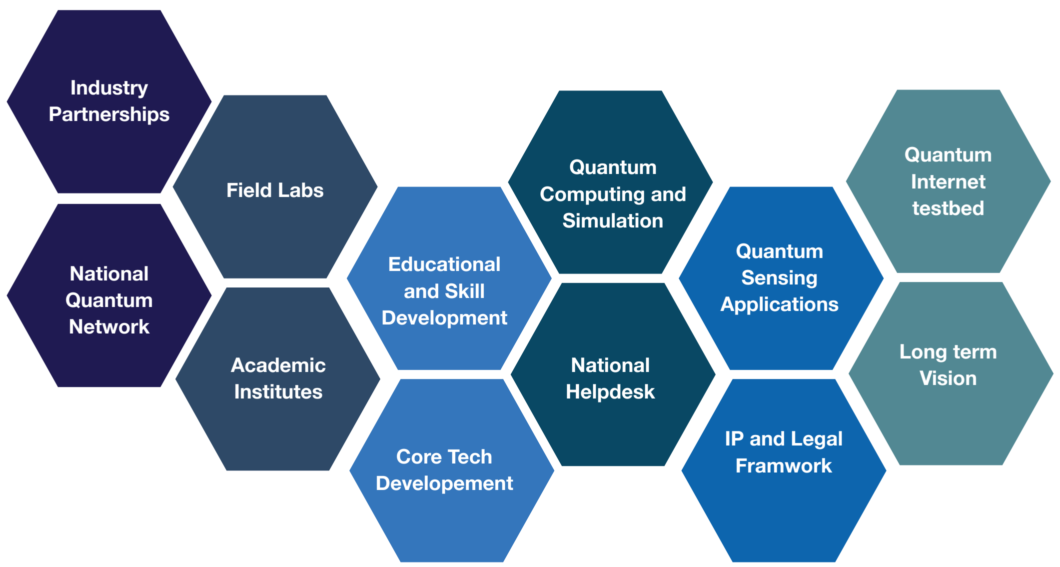


To coordinate and implement the agenda's vision, the initiative evolved into an institutional framework with the establishment of Quantum Delta NL (QDNL) in 2020. QDNL foundation was mandated to align national efforts, facilitate collaboration between universities, start-ups, and industries, and ensure that research outputs would translate into commercial and societal value. Recognizing the importance of sustained investment, the Dutch government awarded €615 million to QDNL in 2021 from the National Growth Fund, within the Dutch Research Council (NWO). This funding enabled the expansion of quantum infrastructure, accelerated talent development, and supported the scaling of deep-tech startups within the Netherlands.

Building on foundational direction provided by NAQT, the momentum of the Netherlands' ecosystem was further reinforced in January 2024, when quantum technology was formally designated as one of ten priority technologies in the Netherlands National Technology Strategy (NTS). This strategic positioning underlines the country's long-term commitment to quantum as both a pillar of national security and a driver of future economic competitiveness. Together, NAQT and NTS form the backbone of the Netherlands' quantum mission, shaping coordinated programs with specific five-year targets and corresponding investments, ten-year outlook, and a roadmap extending to 2035, emphasizing technology maturation, end-user engagement, international collaboration, and fabrication capability expansion.

While NAQT and NTS laid the foundation by focusing on research excellence and community-building, QDNL has advanced the Netherlands' ecosystem into an integrated and coordinated national platform (see Figure 6). This comprehensive vision integrates academic excellence, industrial competitiveness, and international partnerships to secure a resilient and forward-looking quantum future for the Netherlands.

Fig 6: Key elements of the Quantum Ecosystem in Netherlands



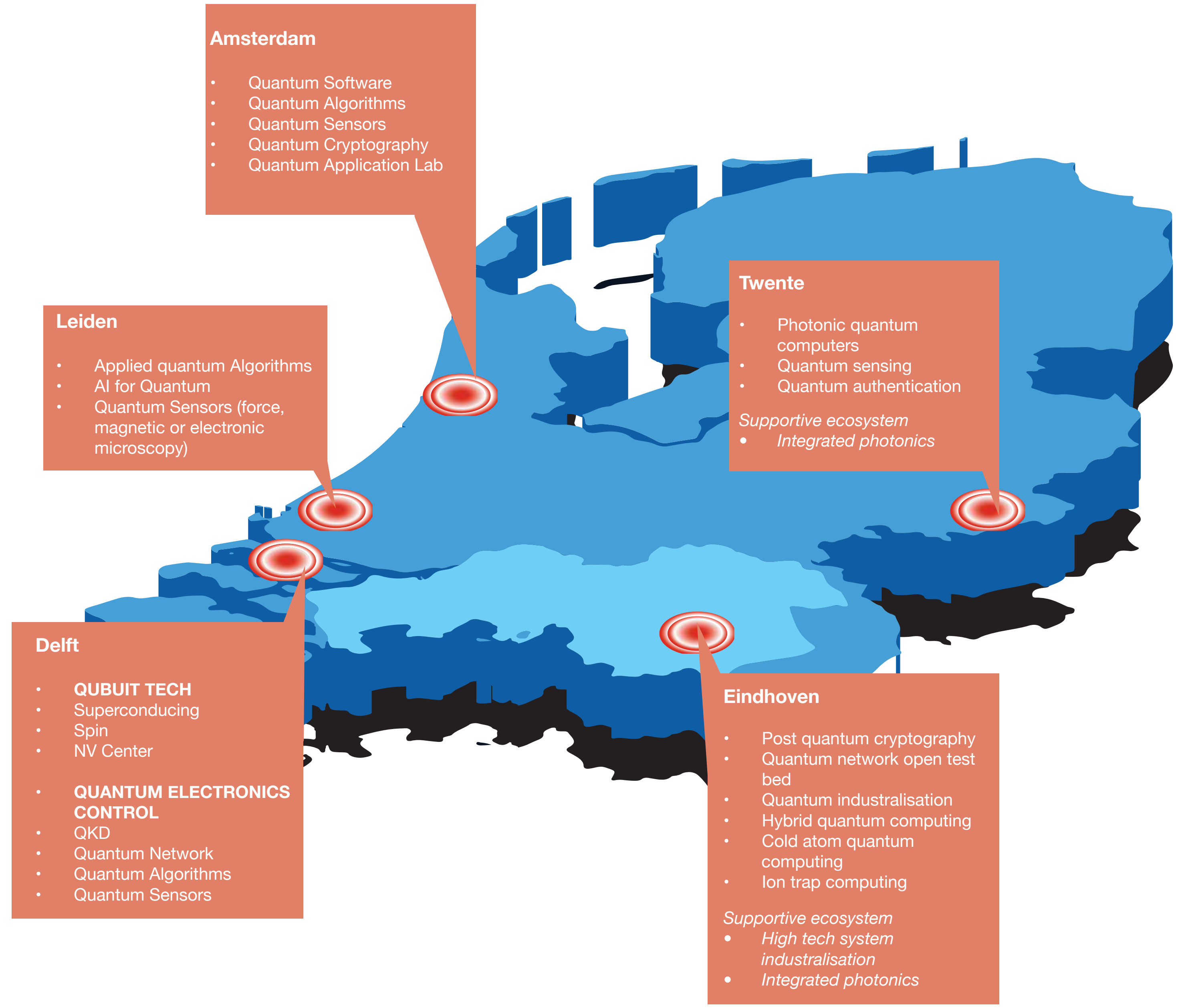
2. Quantum Delta NL and the Five Innovation Hubs

Quantum Delta NL (QDNL) is the central vehicle for executing the Netherlands' national quantum strategy and transforming cutting edge quantum research into real world applications. QDNL integrates national efforts across research, development, and commercialization, anchoring the country's vision for an interconnected and self-sustaining quantum ecosystem.

QDNL is defined by four key action lines identified in NAQT and focuses on three catalyst areas – quantum computing and simulation, national quantum network, and quantum sensing applications. A key part of this infrastructure is-

- **Network of Cleanroom Facilities:** Managed by NanoLabNL . These facilities offer essential nanofabrication capabilities with clean rooms that would otherwise be too expensive for individual research groups or startups. In addition to quantum technology, these resources also serve other sectors such as healthcare, aerospace, semiconductors, and photonics.
- **House of Quantum:** A network of physical spaces across hubs — Delft, Amsterdam, Leiden, Eindhoven, and planned for Twente — offering offices (including co-working spaces), plug-and-play labs, and collaboration space for startups, industry, and researchers.
- **Field Labs:** The field labs facilitate knowledge transfer and interaction between technology push and market pull by providing a space for users to interact with technologies and explore potential use cases.

Fig 7: Five Main Quantum Hubs in Netherlands
Location based capability



QDNL promotes cohesion across academic, industrial, and governmental stakeholders by structuring the Dutch quantum ecosystem around five regional hubs (see Figure 7). This model links research institutions and startups to a national platform for collaboration, technology transfer, and coordinated development; strengthening the Netherlands' long-term position in the international quantum technology landscape. Each hub contributes distinct expertise to this integrated ecosystem:

i. **Delft:** Delft Hub, led by QuTech (a collaboration between TU Delft and TNO), is the Netherlands' hardware and network powerhouse, integrating research and industry through international and national partnerships.

- **Research Focus:** Scalable quantum processors, error correction, quantum networking, quantum internet.
- **Field Lab:** Quantum Inspire (Europe's first public-access quantum computing platform)
- **Notable Startups:** QBlox, QuantWare, Single Quantum, Q*Bird, Orange Quantum Systems, Delft Circuits.
- **House of Quantum:** Located in Delft (main campus).

ii. Eindhoven: Eindhoven is a global photonics hub with a deep-tech manufacturing and telecom base. Led by QT/e (Eindhoven University of Technology), the hub advances photonics-based quantum computing and secure communication systems. QT/e aims to train the quantum engineers and quantum information specialists of the future.

- **Research Focus:** Photonic quantum circuits, quantum light-matter interaction, quantum secure communication.
- **Field Lab**: PhotonDelta Field Lab (Testbed for photonic quantum chips and integrated devices)
- **Notable Startups**: SMART Photonics, EFFECT Photonics, TeraNova, NanoPhab
- **House of Quantum**: Satellite office in Eindhoven (in collaboration with PhotonDelta).

iii. Twente: Set up around the Quant centre of the MESA+ Institute, with a strong photonics and material science base, Twente Hub focuses on nanotechnology for quantum applications, in particular quantum photonics and quantum electronics. Facilities in Twente support lab-to-market transitions through strong industry-academic collaborations.

- **Research Focus:** Quantum materials, hybrid quantum systems, photonic interfaces, nano-device engineering.
- **Field Lab:** NanoLab@Twente (Cleanroom and prototyping facilities for advanced nanofabrication)
- **Startups**: QuiX Quantum, LioniX International.
- **House of Quantum:** Presence planned/associated at Twente via NanoLab and ecosystem partners.

iv. Amsterdam: The Amsterdam hub, anchored by QuSoft (a joint initiative of Centrum Wiskunde & Informatica, University of Amsterdam, and Vrije Universiteit Amsterdam), focuses on quantum algorithms, cryptography, and software, playing a central role in advancing secure communications and optimization solutions. It combines foundational research with real-world applications through strong industry collaborations, while also addressing the societal and ethical dimensions of quantum technology.

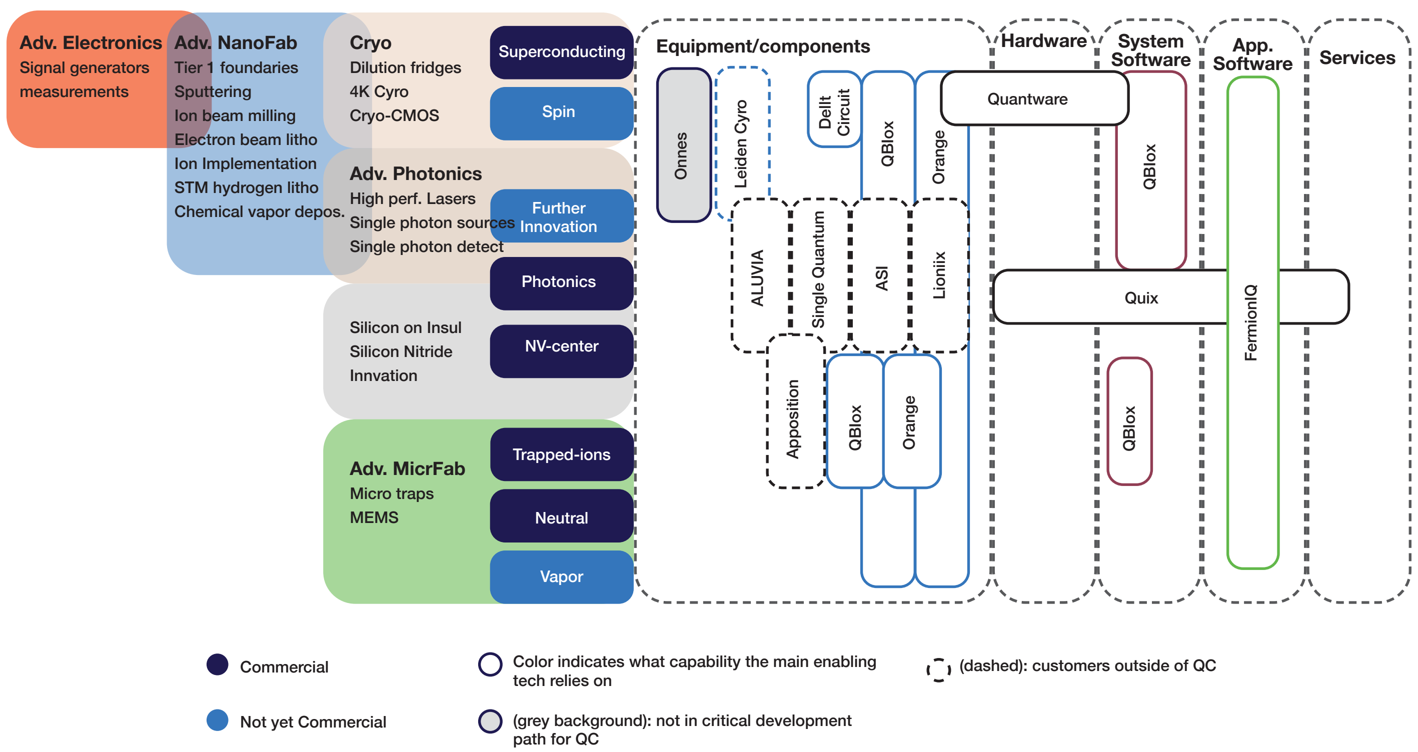
- **Research Focus:** Quantum algorithms, machine learning, cryptography, optimization for real-world problems.
- **Field Lab:** Quantum.Amsterdam Field Lab (Application-driven testing and co-development with industry.)
- **Notable Startups:** Fermioniq, Qu & Co, Amsterdam Scientific Instruments
- **House of Quantum:** Located in Amsterdam (Science Park).

v. Leiden: The Leiden hub focuses on fundamental physics, quantum-enhanced sensing, and applied quantum algorithms, with strong expertise in precision measurement. Industry collaborations SRON, support advances in cryogenic platforms and satellite-based sensing, while the hub also leads outreach on the ethical and legal aspects of quantum technology.

- **Research Focus**: High-precision quantum sensors for magnetic, gravitational, and cryogenic applications.
- **Field Lab:** Leiden Field Lab Quantum Sensing (Real-world sensor validation and prototype testing)
- **Startups:** Leiden Cryogenics, Applied Quantum Algorithms (aQa) Leiden
- **House of Quantum:** Satellite office in Leiden,

Together, these hubs operate as a cohesive network, facilitating the exchange of talent, knowledge, and infrastructure. At the heart of this structure is an emphasis on shared infrastructure, cross-institutional collaboration, and public-private partnerships. The ecosystem is designed to reduce fragmentation, enabling efficient knowledge exchange and joint innovation through coordinated efforts. Through QDNL, there is an integrated approach to follow NAQT's action line by ensuring that the quantum entities in the Netherlands function as part of one ecosystem.

Fig 8: Netherlands' Quantum Computing start-up ecosystem



Source: InvestNL: Venturing into quantum technologies in the Netherlands, Oct 2023

3. Significant Programs and Policy for Supporting Quantum

The Netherlands' quantum ecosystem is underpinned by a portfolio of strategic funding programs, tax incentives, and policy instruments. Through national and EU-level collaboration, the Dutch ecosystem is designed to foster innovation, attract global talent, and accelerate the path from research to market:

Strategic funding and grants initiatives:

At the core of the Dutch quantum strategy lies a robust portfolio of national and European funding initiatives. These programs are designed to support research infrastructure, commercialization pathways, and long-term ecosystem growth. A standout example is the €615 million National Growth Fund (NGF) investment in quantum technology, targeting infrastructure development, R&D, talent building, and ecosystem scaling. This is complemented by the Netherlands' strategic participation in the EU's €1 billion Quantum Flagship, strengthening international collaboration and knowledge exchange.

Other funding instruments include:

- €250 million Invest-NL and Dutch Ministry of Economic Affairs' Deep Tech Fund to support early-stage, including high-risk quantum ventures.
- Quantum Delta NL SME Program, offering targeted assistance to startups and SMEs through grants, mentorship, and R&D support.

Incentives and Tax Benefits:

The Dutch government actively supports private-sector R&D investment in quantum technologies through a range of tax incentives aimed at reducing operational costs and stimulating innovation:

- **WBSO (R&D Tax Credit):** Covers up to 40% of qualifying R&D labor costs. Offers wage tax relief for personnel engaged in IP-generating activities.
- **Innovation Box Regime:** Profits from qualifying R&D and intellectual property are taxed at a reduced rate of 9%, compared to the standard 25.8% corporate tax rate. These incentives aim to attract international talent and encourage domestic innovation.

These incentives make the Netherlands an attractive destination for both domestic and international quantum innovators.

Intellectual Property and Commercialization:
A defining strength of the Dutch quantum ecosystem is its well-integrated, innovation-friendly intellectual property (IP) environment, aligned with EU directives. This encourages public research institutions to transform scientific discoveries into economic value through spin-offs, licensing, and patents. Key elements of the Dutch IP and tech transfer ecosystem include:

- **Technology Transfer Offices (TTOs):** Embedded in universities like TU Delft and Leiden University, TTOs support researchers in patenting, licensing, and launching startups
- **Participation in European IP Frameworks:** The Netherlands is fully integrated into the Unitary Patent and Unified Patent Court systems, allowing streamlined and cost-effective IP protection across Europe.
- **European Patent Cost Reimbursement:** Dutch SMEs and startups benefit from EU schemes like the IP Scan and SME Fund, which subsidize patenting and IP protection costs.
- **Flexible IP Ownership Models:** Public-private partnerships with institutions such as QuTech, TNO, and NWO encourage shared ownership structures that balance research integrity with market competitiveness. Furthermore, QuTech has standardized licensing agreements to accelerate tech transfer and spin-off–friendly policies that empower researchers to commercialize breakthroughs.
- Regional hubs like Amsterdam Science Park and Delft's Quantum Campus offer fast-track startup permits, access to research infrastructure, and proximity to academic and industry partners.

This supportive IP environment ensures that innovations emerging from Dutch labs have clear and efficient pathways to market, attracting global partners and investors alike.

Ecosystem Support

The Netherlands' quantum ecosystem extends beyond policy and funding to include a strong emphasis on talent development and responsible innovation.

Programs led by Quantum Delta NL, under its "Startup & SME Support Program", provide practical support for startups, including legal advisory, IP strategy development, mentorship, and investor matchmaking.

NAQT's Action Line 3 (Human capital- eduaction, knowledge and skills targets the training of over 2,000 quantum-skilled professionals by 2030. This effort include open-access quantum curricula for universities, technical colleges, and vocational schools; and interdisciplinary modules integrating quantum science with engineering, ethics, and entrepreneurship.

Moreover, the ecosystem fosters inclusive innovation through ongoing dialogues on the ethical, legal, and societal dimensions of quantum technology—ensuring the advancement of science aligns with broader public values.

4. Dutch Stakeholders and Quantum Startups

The Netherlands' strength in quantum technology stems from its deeply collaborative ecosystem, where academia, industry, and government operate in well-defined, complementary roles. Academic institutions drive foundational research, startups focus on scalable hardware and software (see Figure 9), industry pilots real-world applications, and government provides strategic direction and funding.

Academic and Research Institutions

Leading Dutch universities and research institutes form the intellectual core of the ecosystem, each with distinct areas of specialization:

- **QuTech (TU Delft & TNO):** Global leader in quantum computing, networking, and internet architecture.
- **QT/e (TU Eindhoven):** Specializes in quantum materials, systems integration, and engineering.
- **QuSoft (University of Amsterdam):** Specializes in quantum software and algorithm development.
- **AQA Institute (Leiden University):** Focuses on near-term algorithmic applications.
- **TNO:** Drives applied research in quantum sensing, space-based communication, and contributes to cybersecurity and policy formulation.

These institutes are coordinated under QDNL, the national platform implementing the Netherlands' Quantum Technology Agenda through aligned R&D, talent development, and commercialization initiatives. These efforts are further bolstered by QDNL thorough field labs, demonstrators, and House of Quantum

Government and Investment Partners

The government supports quantum development through funding, regulation, and strategic oversight:

- **Dutch Research Council (NWO):** Provides research and programmatic funding. Funds scientific research and large-scale quantum programs
- **Ministry of Economic Affairs:** Leads national quantum policy and coordinates public funding. Oversees strategic development.
- **Invest-NL:** Supports quantum ventures via public-private co-investment.

Infrastructure and Applied Innovation

- **Quantum Internet Testbed (Delft–The Hague–Eindhoven):** A landmark collaboration among QuTech (TNO and TU Delft), KPN, SURF, and OPNT, testing entanglement-based communication and Quantum Key Distribution (QKD).
- **Quantum Innovation Testbed (QITT) – TNO:** Offers full-stack hardware validation, from cryogenic systems to control electronics, for startups and academic groups.
- **Quantum Sensing Testbed – TNO:** Develops quantum sensors for navigation, climate monitoring, medical diagnostics, and radar systems, serving industries like aerospace and automotive.
- **TNO Space:** Collaborates with European aerospace partners to develop satellite-based quantum communication systems.
- **Post-Quantum Cryptography – TNO:** Supports Dutch and EU organizations in transitioning to quantum-secure encryption protocols and contributes to national cybersecurity policy.

These facilities ensure the Dutch quantum ecosystem can test, demonstrate, and deploy technologies at scale, accelerating readiness for commercial markets and national infrastructure integration.

Fig 9: Selected Quantum Startups in the Netherlands Ecosystem

COMPANY NAME	CITY	DOMAIN	VALUE CHAIN	QUBIT TYPE
QuiX	Enschede	Computing	Full Stack	Photonics
Quantware	Delft	Computing	Hardware	Superconducting
Qbird	Delft	Communication	Full Stack	Photonics
Qphox	Delft	Comp./Comms.	Hardware	Photonics
LioniX	Enschede	Computing	Hardware	Photonics
Qblox	Delft	Computing	Equip./components	All*
Orange Quantum Systems	Delft	Computing	Equip./components	All*
Single Quantum	Delft	Comp./ Comms.	Equip./components	Photonics
ASI	Amsterdam	Computing	Equip./components	All
Delft Circuits	Delft	Computing	Equip./components	All*
Onnes Technologies	Leiden	Computing	Equip./components	Supercond./Spin
Leiden Cryogenics	Leiden	Computing	Equip./components	Supercond./Spin
FermionIQ	Amsterdam	Computing	Application software	All*
PasQal/ Qu&Co	Amsterdam	Computing	Application software	Neutral Atoms

Source: InvestNL: Venturing into quantum technologies in the Netherlands, Oct 2023

5. International Collaborations

The Netherlands actively engages in strategic international partnerships to bolster its quantum technology ecosystem. These collaborations enhance research capabilities, foster innovation, and integrate Dutch efforts with the global quantum landscape.

European Collaborations

The Netherlands is a key participant in several major EU-led initiatives:

- **Quantum Flagship:** Launched in October 2018 by the European Commission, this €1 billion initiative supports the development of a competitive European quantum industry. Dutch institutions such as QuTech and TNO contribute prominently in areas like quantum internet and precision timekeeping.

- **EuroQCI (European Quantum Communication Infrastructure):** Initiated in 2019 through the EuroQCI Declaration, this project aims to establish a secure pan-European quantum communication network. The Netherlands plays a leading role, drawing on its strengths in quantum networking and cryptography.

- **QuantERA:** Initiated in 2016, QuantERA is a network of national research funding agencies supporting transnational quantum research. Dutch researchers participate in joint projects spanning quantum computing, sensing, and communication.

- **QuIC (European Quantum Industry Consortium):** Established in 2021, QuIC is a non-profit consortium aligning European industry with quantum technology policy and commercialization. Dutch startups, corporates, and research organizations actively contribute to standard-setting and roadmap development.

France-Germany-Netherlands Trilateral Programme:

Launched in November 2022, the France-Germany-Netherlands trilateral initiative aims to reinforce European leadership in quantum technologies through co-funded R&D projects in quantum computing, networking, and sensing; shared infrastructure and cross-border pilot facilities; and public-private collaborations that accelerate innovation and commercial deployment. The program also encourages broader EU participation to foster a more integrated and competitive European quantum ecosystem.

Global Partnerships

The Netherlands maintains strong bilateral collaborations beyond Europe, reinforcing its global integration in the quantum sector:

- **United States:** In February 2023, the Netherlands and the U.S. signed a Joint Statement on Cooperation in Quantum Information Science and Technology. The partnership includes joint R&D, post-quantum cryptography, talent exchange, and commercialization strategies.

- **Canada:** Bilateral ties were formalized in May 2018 through a Memorandum of Understanding between the National Research Council of Canada and the Netherlands Organization for Scientific Research. The collaboration focuses on quantum photonics, sensing technologies, and startup incubation.

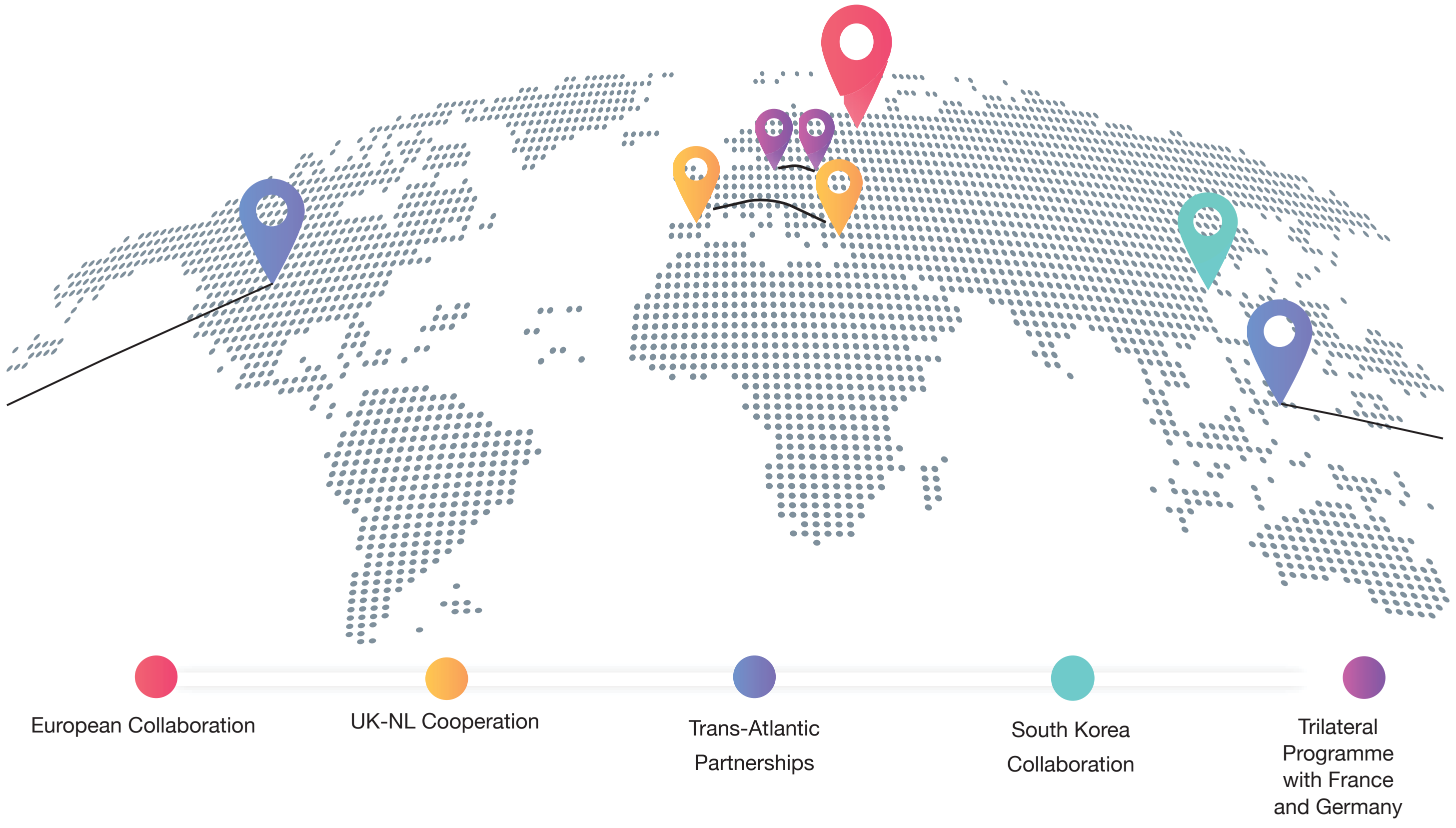
- **Japan:** Through engagements such as the 2024 ASPIRE joint research call, the Netherlands and Japan collaborate on quantum materials, device physics, and academic exchange programs.

- **United Kingdom:** In November 2023, the UK and the Netherlands signed an MoU to enhance cooperation in quantum science and technologies. This includes joint work on technical standards, research security, policy frameworks, and entrepreneurship.

- **South Korea**: In December 2023, the Netherlands and South Korea signed to collaborate on development of innovative technologies including quantum technologies. The MoU was signed during the state visit by South Korean President Yoon Suk-yeol to the Netherlands.

These international collaborations position the Netherlands as a central node in the global quantum technology network—expanding access to expertise, infrastructure, and emerging markets.

Fig 10: International Dutch Collaboration in Quantum



4 The Indian Quantum Ecosystem

1. Evolution of the Quantum Ecosystem in India

India's journey in quantum science and technology has evolved through strategic interventions and visionary policy frameworks, charting a clear path from foundational research to applied innovation and national integration. At the heart of this journey lies a robust commitment to fundamental science, which has long served as a cornerstone for India's progress in quantum science and technologies. As India's digital economy expands, and with flagship initiatives like the National Supercomputing Mission, IndiaAI Mission, and Digital India, the strategic importance of advancing quantum science and technology has become increasingly clear. Positioned at the cusp of a "Techade", a technology-powered decade, India stands to benefit significantly from quantum-driven innovations across sectors. Anticipating the strategic imperative of quantum technologies in shaping India's future, the Department of Science and Technology (DST) launched the Quantum Enabled Science & Technology (QuEST) program in March 2019. This visionary initiative marked India's first structured effort to consolidate and accelerate research in quantum science and technology, supporting foundational R&D across key areas such as quantum processors, sensors, quantum communication, and quantum-enabled devices.

During its initial three-year phase, the program focused on building quantum devices, applications, and human resources. QuEST funded over 50 research projects, carefully categorized into four thematic areas:

1. **Quantum information technologies with photonic devices,**
2. **Quantum information technologies with nitrogen vacancy and magnetic resonance,**
3. **Quantum information technologies with ion-trap and optical lattice devices, and**
4. **Quantum information technologies with superconducting devices and quantum dots.**

The program catalysed the advancement of quantum research and facilitated groundbreaking work on quantum processors, logic gates, single-photon detectors, quantum light sources, quantum sensors, imaging devices, quantum memories, and quantum clocks, while also enabling efforts to demonstrate quantum key distribution and entanglement of distant qubits. With a total investment of ₹186.95 crore (~US$ 21.85 million), QuEST not only nurtured domestic talent and collaboration through a rigorous national selection process but also attracted international attention, positioning India as a key player in the global quantum landscape.

Building on this momentum, in October 2020, DST further strengthened India's quantum research ecosystem by establishing the Technology-Innovation-Hub (TIH) programme at the Indian Institute of Science Education and Research (IISER), Pune. Created under the National Mission on Interdisciplinary Cyber-Physical Systems (NM-ICPS), this hub represents a significant investment of ₹170 crore (~US$ 19.88 million) and focuses on translating research outcomes into scalable and industry-relevant solutions.

While QuEST laid the foundation by nurturing fundamental research and fostering collaboration, the National Quantum Mission (NQM) builds on this vision with a focus on large-scale deployment, commercialization, and the seamless integration of quantum technologies into India's industrial and digital ecosystems.

The National Quantum Mission (NQM), approved by the Union Cabinet on April 2023, with a total outlay of ₹6003.65 crore (~US$ 701 million) for a period of 8 years. The mission is designed to seed, nurture, and scale up both scientific and industrial R&D while fostering a vibrant and innovative ecosystem for Quantum Technologies and Applications (QTA). By supporting sectors such as communication, healthcare, finance, energy, space, banking, and security NQM aims to drive quantum-led economic growth and establish India as a global leader in this transformative field.

The mission also complements national priorities like Digital India, Make in India, Start-up India, Aatmanirbhar Bharat, and the Sustainable Development Goals (SDGs), while providing synergy with other flagship programs such as the National Supercomputing Mission (NSM), India Semiconductor Mission (ISM), and the National Mission on Interdisciplinary Cyber-Physical Systems (NM-ICPS).

Quantum technologies hold strategic significance for India, not only in strengthening technology security and national competitiveness but also in advancing the country's position within the global technology landscape.

2. National Quantum Mission and the Four Thematic Hubs

The National Quantum Mission (NQM) represents a pivotal step in India's strategy to harness the transformative potential of quantum technologies. Launched in 2023, the Mission is designed to accelerate the development, deployment, and integration of quantum solutions across critical sectors, strengthening India's technological security, global competitiveness, and innovation capacity.

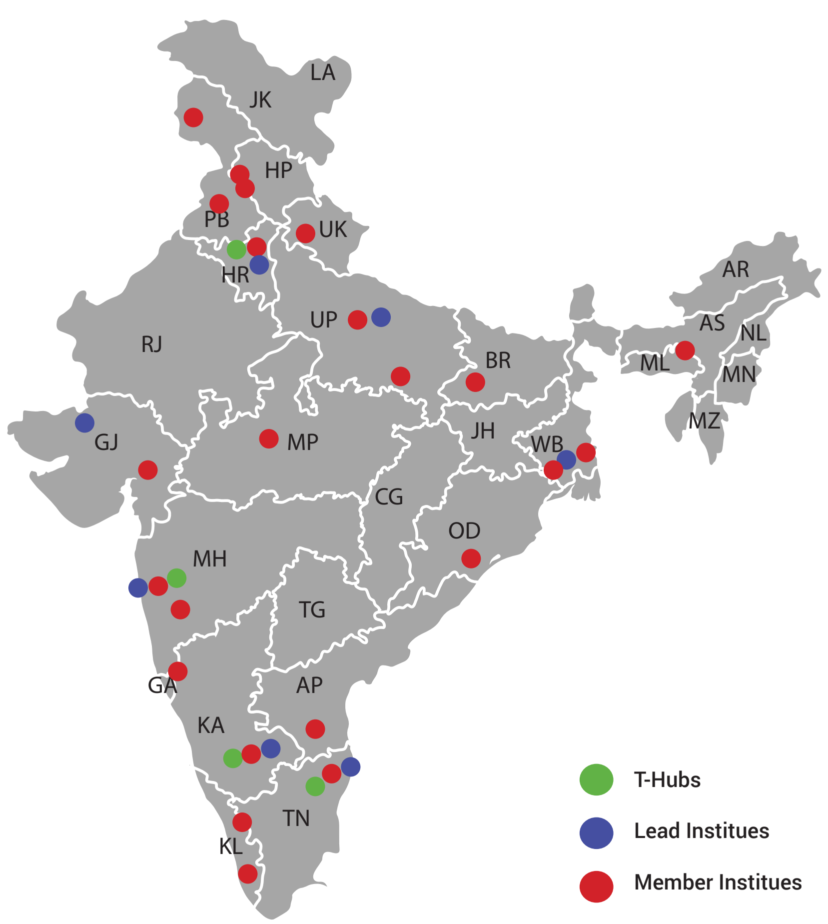
By adopting a mission-oriented approach, NQM aims to translate cutting-edge research into real-world applications through well-defined, measurable outcomes across its thematic focus areas. The Mission not only nurtures scientific discovery but also fosters industry collaboration, international partnerships, and entrepreneurship, ensuring the growth of a dynamic and self-sustaining quantum ecosystem. NQM has been particularly effective in incentivizing the creation of new laboratories and research groups working on quantum technologies across the country.
The Mission's overarching objectives include the development of quantum computers, highly secure quantum communication systems leveraging Quantum Key Distribution (QKD) and Post-Quantum Cryptography (PQC), quantum clocks and sensors, quantum materials and devices, as well as human resource development, global collaborations, and the nurturing of an ecosystem of quantum technology startups.

By adopting a mission-oriented approach, the program aims to expedite the maturation of technologies to high Technology Readiness Levels (TRLs). To ensure trust, security, and real-world readiness, NQM is also establishing testing and certification facilities for quantum technologies — a crucial step for validating quantum security solutions and encouraging industry-wide adoption.

Researchers are advancing quantum algorithms, tackling error correction, and developing hardware using superconducting circuits, trapped ions, and quantum dots. Efforts in secure communication protocols and quantum sensing are also gaining momentum. This inherently interdisciplinary field bridges computer science, materials science, electronics, and biology, addressing challenges in qubit coherence, scalability, and real-world applications across sectors like healthcare, energy, and security.

A key component of the Mission's implementation strategy is the establishment of four Thematic Hubs (T-Hubs) at leading academic and national R&D institutions. The four T-Hubs selected under NQM collectively involve 152 researchers from 43 institutions nationwide, fostering a collaborative ecosystem to drive research and innovation in quantum technologies (see Figure 11). The activities carried out by these hubs include technology and application development, human resource development, entrepreneurship development, industry partnerships, and international collaborations.

Fig 11: NQM Thematic Hubs and Technical Groups



T- HUBS	LEAD INSTITUTES
Quantum Computing	IISc Banglore
Quantum Communication	IT Madras
Quantum Sensing and Metrology	IIT Bombay,
Quantum Materials and Devices	IIT Delhi

Each T-Hub follows the Hub-Spoke-Spike model, fostering a cluster-based network where research projects (Spokes) and individual research groups (Spikes) operate alongside central hubs. This structure enhances collaboration among research institutions, allowing for effective knowledge-sharing and resource optimization. Mission Implementation includes setting up of four Thematic Hubs (T-Hubs) in top academic and national R&D institutes:

i. Thematic Hub for Quantum Computing: Indian Institute of Science Bengaluru

- **Institutions Involved:** IIT Delhi, IIT Kanpur, IIT Roorkee, IIT Bombay, IIT Madras, IIT Ropar, IIT Guwahati, IIT Patna, BITS Hyderabad, IMSc Chennai, JIIT Noida, SETS Chennai, CDAC Bengaluru, IIT Indore, IISER Thiruvananthapuram, IISER Pune, RRI Bengaluru, NISER Bhubaneswar, TIFR Mumbai, TIFR Hyderabad and JNCASR Bengaluru
- **Objective:** Develop intermediate-scale quantum computers with 20-50 physical qubits (3 years), 50-100 physical qubits (5 years) and 50-1000 physical qubits (8 years) in various platforms like superconducting and photonic technology.

ii. Thematic Hub for Quantum Communication: IIT Madras

- **Institutions Involved:** ISRO Ahmedabad, ISRO Satellite Centre, IIT Delhi, IIT Kanpur, IIT Kharagpur, IIT Bhilai, IIT Roorkee, IIT Jammu, IIT Tirupati, IIT Patna, IIT Indore, IIT Hyderabad, IISc Bengaluru, IISER Bhopal, IISER Mohali, RRI Bengaluru, HRI Prayagraj, IIST DOS Thiruvananthapuram, C-DAC Bengaluru, C-DAC Thiruvananthapuram and SETS Chennai
- **Objectives:**
  - Develop satellite-based secure quantum communications between two ground stations over a range of 2000 kilometres within India, as well as long-distance secure quantum communications with other countries.
  - Develop inter-city quantum key distribution over 2000 km with trusted nodes using wavelength division multiplexing on existing optical fibre.
  - Develop a multi-node quantum network with quantum memories, entanglement swapping, and synchronised quantum repeaters at each node (2-3 nodes).

iii.Thematic Hub for Quantum Sensing and Metrology: IIT Bombay

- **Institutions Involved**: IISc Bengaluru, IIT Madras, IIT Delhi, IIT Kanpur, IIT Gandhinagar, IISER Bhopal, IIT Ropar, TCG CREST Chennai, TIFR Bombay, TIFR Hyderabad, HRI Prayagraj, IACS Kolkata, BITS Goa, University of Hyderabad and SN Bose NCBS
- **Objective:** Develop magnetometers with 1 femto-Tesla/$\sqrt{Hz}$ sensitivity in atomic systems and better than 1 pico-Tesla/$\sqrt{Hz}$ sensitivity in Nitrogen Vacancy (NV) centers. Develop gravity measurement systems with sensitivity better than 100 nanometer/second^2 using atoms, and atomic clocks with 10^{-19} fractional instability for precision timing, communications, and navigation

iv.Thematic Hub for Quantum Materials and Devices: IIT Delhi

- **Institutions Involved:** IIT Bombay, IIT Madras, IIT Kanpur, IIT Roorkee, IIT Kharagpur, IIT Bhubaneswar, SSPL- DRDO Delhi, IACS Kolkata and IISER
- **Objective:** Develop novel materials for the fabrication of quantum devices, including qubits for quantum computing and quantum communication applications, single-photon sources and detectors, and entangled photon sources for quantum communication, sensing, and metrological applications.

Under NQM, dedicated efforts are underway to develop quantum-resilient encryption techniques and post-quantum cryptographic (PQC) frameworks, ensuring India's critical database systems remain secure in the quantum era. Key initiatives include:

- **Quantum-Safe Ecosystem Framework:** A concept paper has been developed to outline a strategic roadmap for securing and strengthening India's digital infrastructure against quantum threats.
- **DRDO Initiatives**: The Defence Research and Development Organization (DRDO) is leading projects focused on designing and testing quantum-resilient security schemes, along with quantum-safe symmetric and asymmetric key cryptographic algorithms.

- **Advancements by SETS:** The Society for Electronic Transactions Security (SETS), under the Office of the Principal Scientific Adviser (PSA), is accelerating Post-Quantum Cryptography (PQC) research. It has implemented PQC algorithms for applications such as Fast IDentity Online (FIDO) authentication tokens and Internet of Things (IoT) security.

- **C-DOT Innovations:** The Centre for Development of Telematics (C-DOT), under the Department of Telecommunications(DoT), has developed cutting-edge solutions, including fiber-based Quantum Key Distribution(QKD), and Quantum Secure Video IP Phones.

These initiatives are crucial for safeguarding India's digital infrastructure against emerging quantum-era cybersecurity threats.

3. Significant Programs and Policy for Supporting Quantum

Beyond the foundational National Quantum Mission (NQM) and the Quantum-Enabled Science and Technology (QuEST) program, India has steadily expanded its quantum science and technology (QST) ecosystem through a constellation of institutional initiatives, public-private partnerships, and emerging policy frameworks. These efforts collectively signify India's ambition to build a future-ready quantum innovation ecosystem that integrates advanced R&D, commercialization, talent development, and strategic applications.

Institutional Programs and National Initiatives

Several government-led initiatives reflect India's broad commitment to harnessing quantum technologies across sectors:

- **MeitY Quantum Computing Applications Lab:** Launched in 2021 in partnership with Amazon Web Services (AWS), Ministry of Electronics and Information Technology's (MeitY) lab enables Indian public sector institutions, academia, and startups to access quantum computing platforms and solve real-world problems. It plays a key role in democratizing access to quantum resources.

- **India Quantum Alliance (C-DOT):** The Department of Telecommunications has established the India Quantum Alliance under C-DOT, fostering collaboration between academia, industry, and startups to drive the development of indigenous quantum communication technologies.

- **DRDO Young Scientist Laboratory – Quantum Technologies (DYSL-QT), Pune**: Focused on early-stage quantum R&D, this lab aims to enhance TRLs from 1 to 5, and eventually to 9, across quantum computing, communication, and sensing technologies for defense applications.

- **Metro Area Quantum Access Network (MAQAN):** India's first quantum communication testbed, MAQAN is being developed in Chennai, connecting IIT Madras, IITM Research Park, the Society for Electronic Transactions and Security (SETS), and the National Informatics Centre (NIC). It aims to build standards and protocols for metro-scale quantum communication networks.

- **SETS Quantum Security Research Lab:** Operational from June 2024, this lab works alongside the Bureau of Indian Standards (BIS), MeitY, and Telecom Standards Development Society, India (TSDSI) to establish national standards for quantum-era cybersecurity, focusing on cryptographic resilience, quantum key distribution (QKD), and quantum-safe systems aligned with global best practices like those of NIST (USA). For citizen-centric applications, SETS is working alongside the Controller of Certifying Authorities (CCA), MeitY, and domain experts to establish guidelines for migrating to PQC in the Public Key Infrastructure (PKI) ecosystem

- **ISRO's Quantum Initiatives:** The Indian Space Research Organisation is exploring quantum applications in space, especially satellite-based QKD and quantum sensors for secure communication and remote sensing.

- **C-DAC Quantum Initiatives:** The Centre for Development of Advanced Computing (C-DAC) is advancing indigenous quantum computing capabilities through the development of quantum simulators, toolkits, and prototype processors. It is also building quantum applications in cryptography, optimization, and materials science. As part of its capacity-building efforts, C-DAC offers specialized training programs to researchers and professionals, integrating quantum modules into its high-performance computing and advanced ICT education platforms. C-DAC, in collaboration with IISc Bangalore and IIT Roorkee, has developed Quantum Computer Simulator Toolkit simulator/workbench that allow users to simulate quantum circuits with realistic noise on HPC systems.

- **Department of Atomic Energy (DAE):** DAE supports research in quantum materials, quantum coherence, and quantum simulation through its network of premier institutions such as TIFR, RRCAT, and IGCAR. The focus is on foundational science and enabling technologies that contribute to scalable quantum systems, particularly in quantum computing and high-precision measurement.

- **Department of Biotechnology (DBT):** DBT is actively exploring quantum-enabled biomedical sensing and diagnostics, especially in the context of high-sensitivity imaging, quantum-enhanced biosensors, and advanced drug discovery platforms. These initiatives aim to integrate quantum tools into next-generation healthcare technologies.

Innovation Support and Startup Ecosystem Development

Recognizing the strategic importance of quantum technologies, India is increasingly directing funding and innovation support toward startups and deep-tech ventures:

- **Startup Grants under NM-ICPS and NQM:** In a transformative policy shift, quantum startups are now eligible for grants ranging from ₹0.5 to ₹50 crore (~US$ $59,500 to US$ 5.95 million) under the Technology Innovation Hubs (TIHs) of the National Mission on Interdisciplinary Cyber-Physical Systems (NM-ICPS) and National Quantum Mission. This marks a significant milestone in mainstreaming startup-led innovation in the QST space.

- **Venture Funding Landscape:** Despite promising developments, India's deep-tech investment landscape remains under-penetrated. Unlike international ecosystems driven by venture capital, India's quantum startups primarily rely on angel investors and public funding. There is a growing call for policy mechanisms—such as government-backed VC funds, blended finance models, and corporate investment consortia—to attract institutional capital.

Human Capital and Education Programs

Human resource development remains central to India's quantum ambitions:

- **Quantum Education Curricula:** In December 2024, the DST and AICTE (All India Council For Technical Education) launched a model undergraduate minor curriculum in quantum technologies, open to all engineering disciplines from the third semester onwards. DST and AICTE are also currently developing a standardized Masters-level program for Quantum. To support national-level adoption DST and AICTE have initiated several Faculty Development Programs across India. This is part of a national strategy to embed quantum science in higher education.

- **University and Corporate Programs:** Several academic institutions have launched dedicated degree and certificate programs in quantum technologies. In parallel, companies like IBM, TCS, Tech Mahindra, Amazon, Qkrishi, Harman International, Artificial Brain, and Quantum AI Global are offering industry-aligned training, often in partnership with universities such as BITS Pilani, Mahindra University, and Christ University.

- **Quantum Entanglement Exchange (Quantum EE):** India is a participant in Quantum EE, a multinational exchange platform, hosting a portal under the DST to attract global talent—students, postdocs, and professionals—for research opportunities in India's quantum labs and institutions.

Allied Foundational Programs

India's quantum strategy also leverages foundational science and emerging technology missions:

- **Mission on Nano Science & Technology (Nano Mission):** Though concluded in 2017, this DST-led mission laid vital groundwork for advanced materials research critical to quantum hardware. It also established the Institute of Nano Science and Technology (INST), Mohali, a key node in the QST landscape.

- **National Mission on Interdisciplinary Cyber-Physical Systems (NM-ICPS):** This mission hosts several

Technology Innovation Hubs, including the I-Hub Quantum Technology Foundation at IISER Pune, which plays a catalytic role in quantum R&D and ecosystem development.

Policy Framework and Future Outlook

While India has not yet introduced a dedicated tax incentive or intellectual property (IP) policy tailored exclusively for quantum technologies, some supportive frameworks are emerging:

- **Startup India and R&D Tax Provisions:** Startups in the quantum space may benefit from broader provisions under the Startup India program, including tax holidays, exemptions on capital gains, and expedited IP filing under the Scheme for Facilitating Start-Ups Intellectual Property Protection (SIPP).

- **Intellectual Property Ecosystem:** India's evolving IP infrastructure supports quantum innovations through faster patent examinations and fee reductions for recognized startups. However, a sector-specific IP and standards policy for quantum is still in nascent stages and represents a critical area for policy advancement.

4. Indian Stakeholders and Quantum Startups

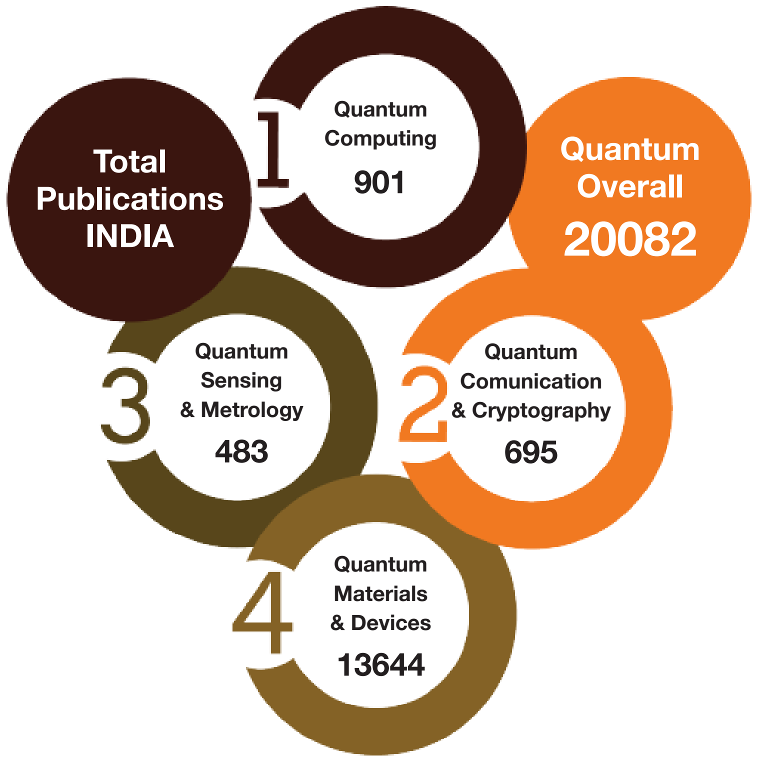
Academic and Research Institutions

India's academic and research landscape in quantum technologies is anchored by premier institutions such as IISc Bengaluru, TIFR Mumbai, RRI, and several IITs—including Bombay, Madras, Delhi, Kanpur, Kharagpur, and Hyderabad. These institutions lead foundational research in quantum computing, materials, optics, and communication (see Figure 12). Emerging players like Mahindra University and IIIT Kottayam have developed robust quantum research programs through industry-academic collaborations, while IIT Madras, IISERs, IIIT Hyderabad, and Ashoka University are exploring interdisciplinary applications in fields such as quantum biology, chemistry, and finance.

Several institutions have also launched collaborative research programs with national and global tech firms, particularly in quantum simulation, machine learning, and post-quantum cryptography. Innovation hubs are rapidly growing in Bengaluru, NCR, and Hyderabad, with new activity expanding into Mumbai, Pune, and Chennai—supported by the establishment of Quantum Thematic Hubs in these regions.

India is also recognized among the top 10% of contributors to high-impact global quantum research publications. Notably, unlike traditional sectors, startups and enterprises in the quantum space are prioritizing in-house R&D with dedicated infrastructure, including advanced laboratories for quantum hardware and algorithm development.

Fig 12: India's Quantum Publications Landscape



Government and Investment Partners

Alongside the National Quantum Mission (NQM), agencies such as the Department of Science & Technology (DST), Ministry of Electronics and IT (MeitY), Department of Telecommunications (DoT), and the Office of the Principal Scientific Adviser (PSA) are instrumental in advancing India's national quantum infrastructure.

Since 2021, awareness and interest in quantum technologies have grown significantly within India's investment and corporate sectors. By early 2025, at least four quantum startups had secured venture capital funding—marking a notable shift from an earlier angel-driven landscape. The Indian technology sector, bolstered by a strong IT foundation, is increasingly recognizing quantum's transformative potential. Leading corporations such as TCS, Bharat Electronics Limited (BEL), Indian Oil Corp., and L&T are actively investing in quantum R&D and applications, further accelerating ecosystem growth.

Quantum Startups:

India's quantum startup ecosystem has witnessed remarkable growth, expanding from just 6 startups in 2021 to over 65 by early 2025 (see Figure 13). These ventures span diverse domains, including:

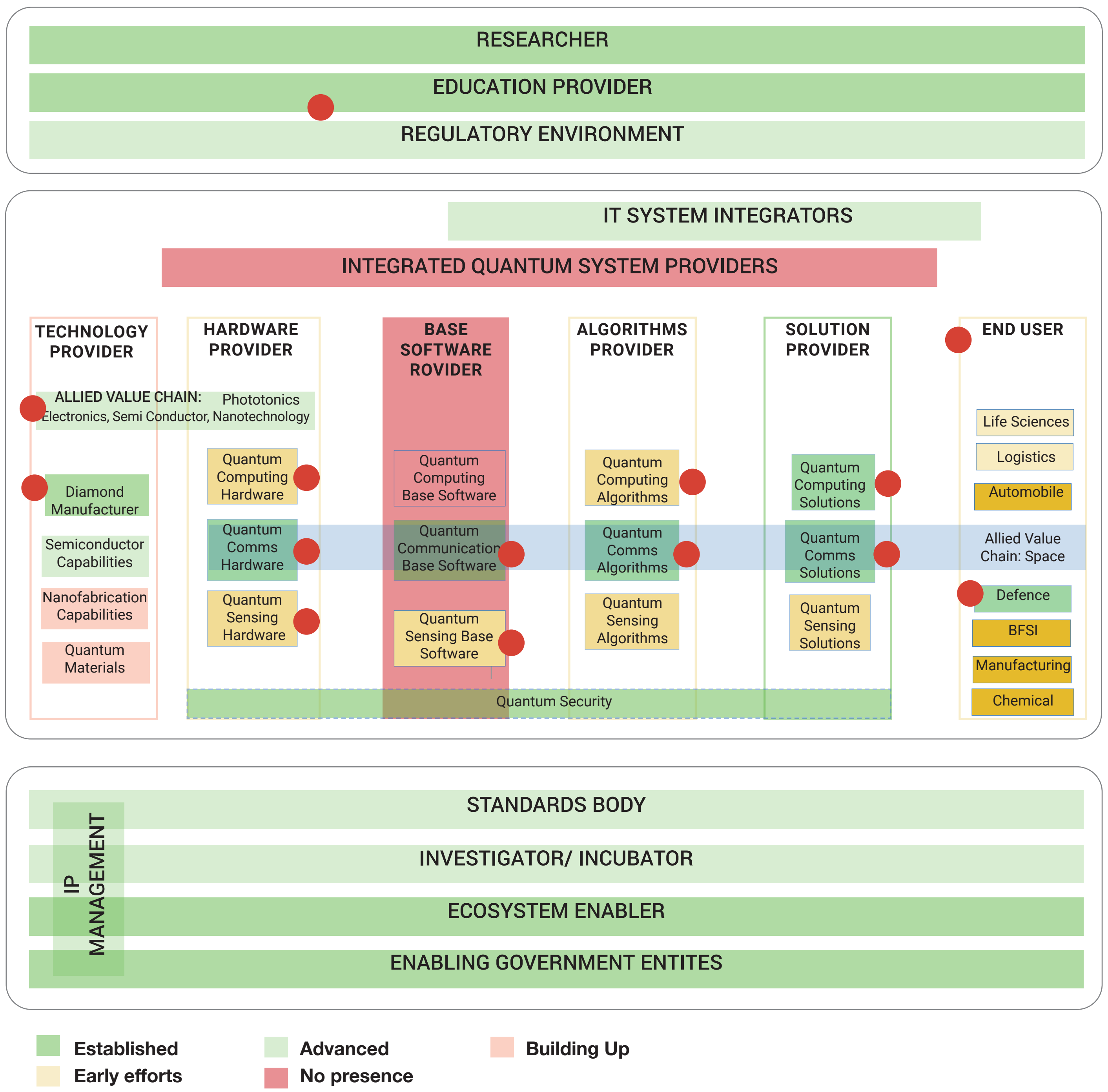
- **quantum computing (45 startups)**
- **quantum communication and cryptography (13)**
- **quantum materials and devices (8)**
- **quantum sensing and metrology (3)**

Fig 13 : Selected Quantum Startups in the Indian Ecosystem

Name	Area of Operation	Place	Hardware/Software and Services
Quantum AI Global	Quantum Solutions	Hyderabad	Hardware and Software Services
QNu Labs	Quantum Communications, Quantum Security	Bengaluru	Hardware
TAQBIT Labs	Quantum Communications, Quantum Security	Bengaluru	Hardware
Quanfluence	Quantum Computing	Bengaluru	Hardware
QpiAI	Quantum Computing, Solutions and Education	Bengaluru	Hardware
QClairvoyance Quantum Labs	Quantum Security	Hyderabad	Hardware and Software
Spectral Instrument Systems	Quantum Sensing	Haryana	Hardware
QKrishi	Quantum Solutions	NCR	Software and Services
BosonQ Psi	Quantum Solutions	Bhilai	Software and Services
Qbit Labs	Quantum Solutions	NCR	Software and Services
QRACE (Quantum Research and Centre of Excellence)	Research, Consulting	NCR	Software and Services
Diamond Elements	Diamonds for NV Centre and Precision Electronics	Surat	Materials
PrenishQ	Control Systems and Components for Quantum Computing	NCR	Hardware
Quan2D Technologies	Quantum Nanomaterials	Bengaluru	Materials
Fortytwo Labs	Quantum Security	Pune	Software and Solutions
Secure Machines	Quantum Security	Bengaluru	Software and Solutions

The Department of Science and Technology's (DST) 2024 call under the National Quantum Mission (NQM) and NM-ICPS selected eight startups for funding across quantum communication, computing, and sensing. Notable recipients include QNu Labs (Bengaluru), a pioneer in quantum-safe encryption and QKD systems, and QPiAI (Bengaluru), which has launched a 25-qubit superconducting quantum processor. Other selected startups, such as Dimira Technologies (an IIT-Mumbai spinout) and Quanastra, are developing enabling components like cryogenic cabling and superconducting detectors. This rapid rise reflects both growing investor interest and increased awareness of quantum technologies. Startups are drawing on India's strong technical talent pool, with innovation hubs forming in Bengaluru, NCR, and Hyderabad, and expanding into Mumbai, Pune, and Chennai—supported by the development of regional hubs. Encouragingly, many startups are prioritizing in-house R&D, establishing advanced labs and infrastructure—marking a cultural shift from traditional industry norms and reinforcing India's emerging leadership in quantum innovation (see Figure 14).

Fig 14: Startups Presence across the Quantum Value Chain in India



The figure on the opposite page represents the Quantum Value Chain in detail. The value chain can be studied in two parts:

- *The supply chain – The central big box in the above representation includes elements of the supply chain*
- *The horizontal layers and additional elements which when included provide an overview of the overall Value Chain and can represent non supply chain ecosystem elements -The 2 together describe the way value flows within the ecosystem and also elements that provide value across the Value Chain, e.g. Standard bodies or Ecosystem Enabling*

The evaluation of the relative strengths of various elements within a national =value chain is done by evaluating the results of the interviews and secondary research and applying that to the Value Chain Diagram by colour coding the value chain as follows: (a) Dark Green – Established, (b) Light Green- Advanced, (c) Orange – Building Up, (d) Yellow – Early efforts , and (e) Red – No presence

Quantum NGOs and Not-for-profit Organizations:

A growing number of nonprofit organizations in India, including QETCI, are actively contributing to quantum science and technology (QST) through education, research, and talent development. Quantum Research and Centre of Excellence (QRACE) engages in applied research through partnerships with academia and industry—such as with Hyundai on quantum-inspired routing and Agra University on quantum Schrödinger channels. QIndia is committed to grassroots quantum education, offering hands-on training workshops like QBronze (2021–2022) to equip learners with core skills in algorithms such as Grover's and Shor's. Together, these organizations play a vital role in democratizing quantum knowledge and fostering a broader, inclusive talent pipeline in India.

5. International Collaborations in Quantum for India

US-India Engagement:

- The U.S.–India Initiative on Critical and Emerging Technology (iCET), launched in May 2022, seeks to strengthen strategic technology partnerships and defence industrial cooperation between governments, academia, and the private sector. Under iCET, the U.S.–India Quantum Coordination Mechanism, led by the National Security Advisors (NSAs), is driving bilateral collaboration in Quantum Information Science and Technology. Key activities include joint workshops on post-quantum cryptography and quantum hardware, and expert exchanges with U.S. national laboratories.

- In August 2024, the U.S.-India Quantum Coordination Mechanism held its second meeting in Washington, where both countries announced seventeen new joint AI and quantum R&D awards under the U.S.–India Science and Technology Endowment Fund (IUSSTF). Additionally, IBM signed MoUs with the Government of India to integrate its Watson platform with India's AIRAWAT supercomputer, advancing AI innovation, semiconductor R&D, and support for the National Quantum Mission. IBM is also partnering with TCS and Government of Andhra Pradesh to deploy 156-qubit IBM Heron processor at Quantum Valley Tech Park, Amaravati.

- Further deepening this engagement, the U.S.–India TRUST (Transforming the Relationship Utilizing Strategic Technology) initiative was launched in February 2025 to catalyse collaboration across critical and emerging technologies, including quantum, AI, semiconductors, space, energy, and biotechnology.

UK-India Engagement:

In November 2023, the UK–India Quantum Technologies Working Group brought together industry and academia from both countries to build a shared knowledge base on quantum research priorities and policies. Building on this foundation, the UK-India Technology Security Initiative (UK-India TSI), launched in July 2024 as part of the broader India-UK Roadmap 2030. The initiative focuses on critical and emerging technologies, including quantum, and promotes collaboration through joint hackathons, entrepreneurship training, and academic exchanges to strengthen industrial quantum capabilities. The TSI is coordinated by the NSAs of India and the U.K. through a combination of existing and newly established dialogues.

Australia-India Engagement:

The Australia-India Cyber and Critical Technology Partnership (AICCTP), established in 2020, supports collaborations on cyber and critical technology issues. The partnership deepens institutional, research, business, and government linkages through research grants, policy exchanges, information sharing, and awareness-raising activities.

QUAD Cooperation:
The Quad QUIN Quantum Information Sciences Center of Excellence (QCoE), launched in November 2023, fosters investment and collaboration in quantum computing, communications, sensing, ecosystem building, and workforce development across India, Japan, Australia, and the U.S. The QCoE is co-chaired by leading science advisors from all four nations, including India's Principal Scientific Adviser.

Europe-India Engagement:

- The EU-India Trade & Technology Council (EU-India TTC), launched in February 2023, prioritises quantum technologies under Working Group-1 (Strategic Technologies, Digital Governance, and Digital Connectivity). The collaboration particularly focuses on joint work with High-Performance Computing research projects aimed at addressing global challenges.

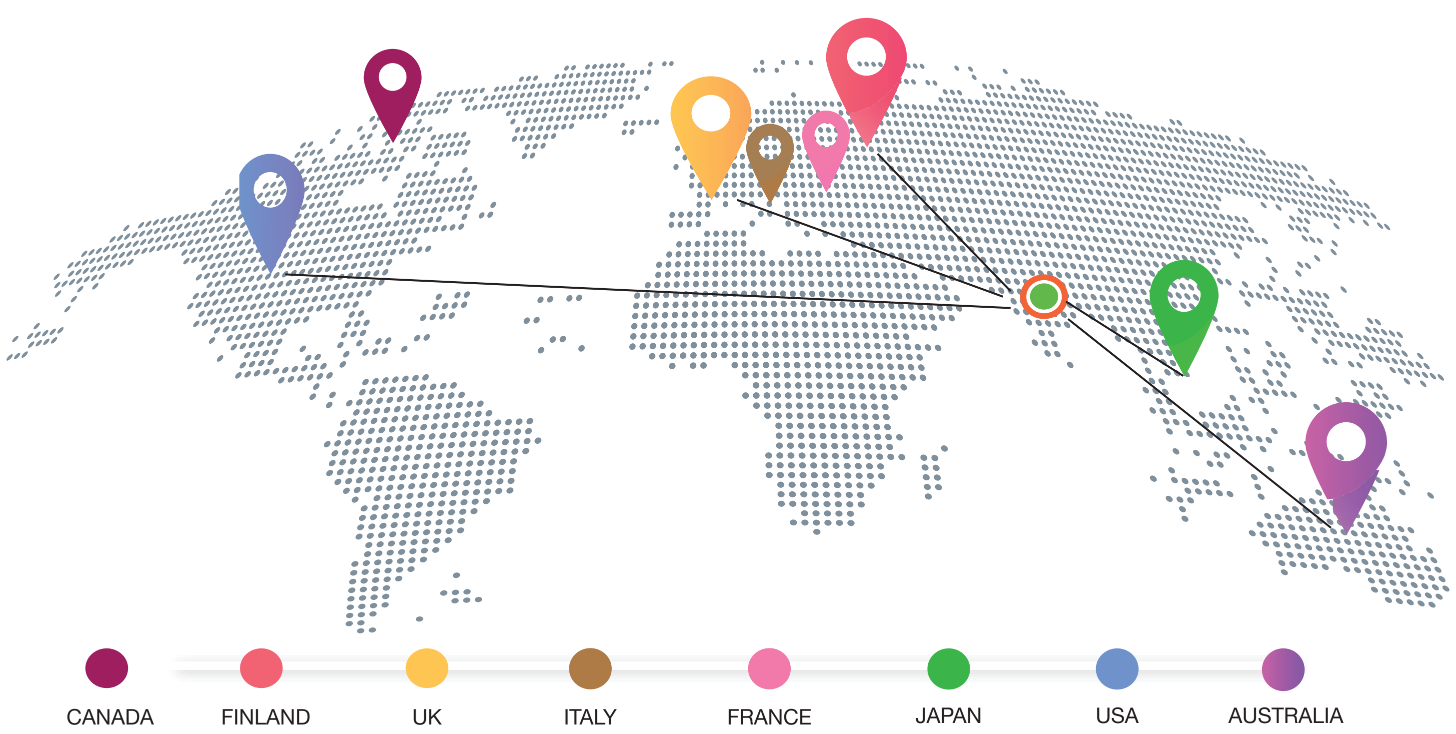
- In July 2024, a joint call for proposals for India-EU cooperation on High Performance Computing and Quantum technologies was announced. This call was to support the implementation of the EU-India High Performance Computing and Quantum Technologies Agreement on 21st November 2022.

Global Partnerships:

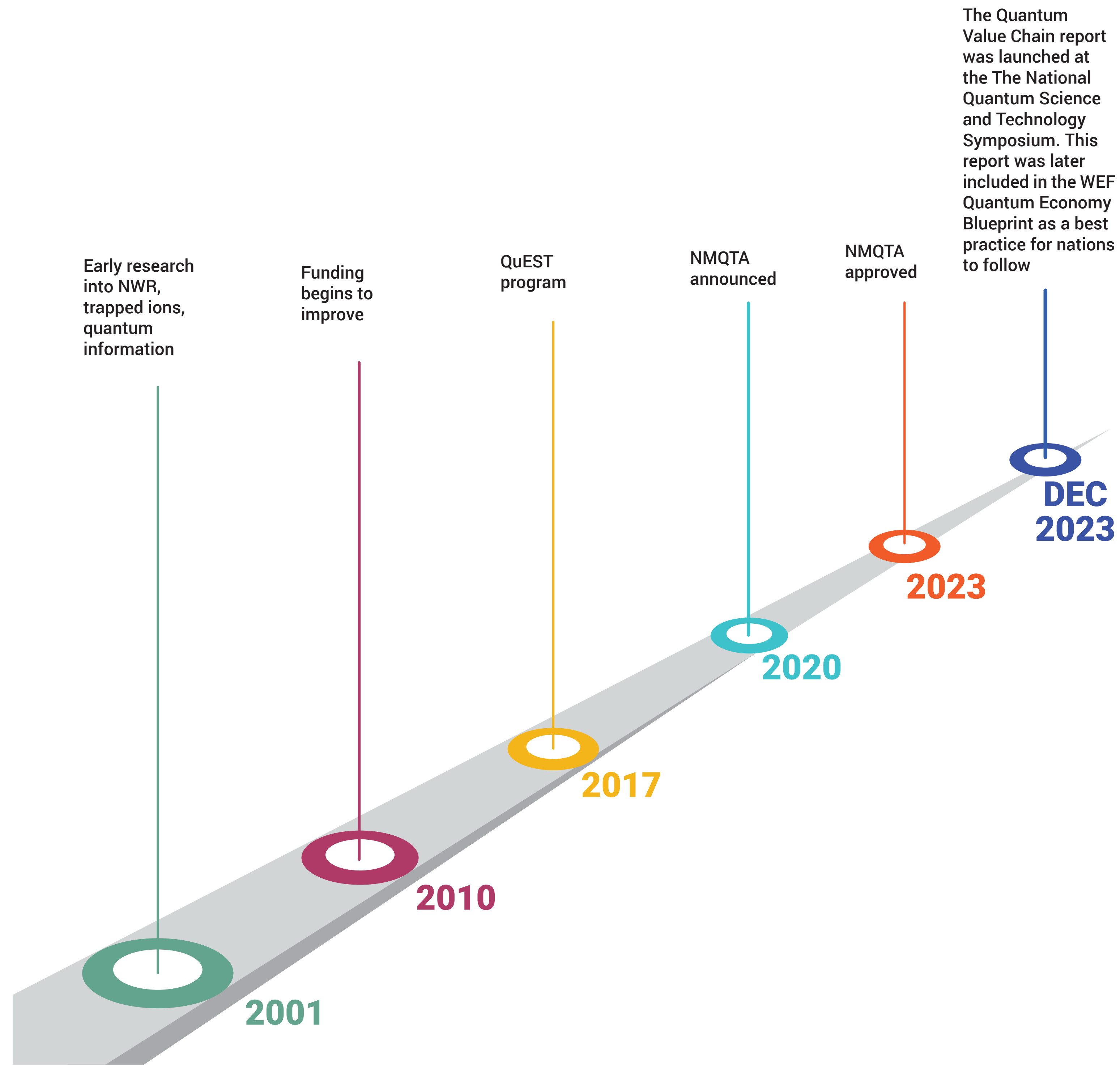
- India is also engaged in international cooperation through Memorandums of Understanding (MoUs), Joint S&T Committees, and working group aimed at fostering joint R&D, institutional exchanges, and commercialization. Some of India's partners in quantum are:
  - o Canada (2022)
  - o France (2023)
  - o Israel (2023)
  - o Finland (2023)
  - o Japan (2024)
  - o Italy (2025)

- India is engaged in leading international platforms including:
  - o Chicago Quantum Exchange (CQE) – with IIT Bombay as a partner.
  - o Quantum Economic Development Consortium (QED-C) – with S.N. Bose National Centre for Basic Sciences, Kolkata as a member.

Fig 15: International Indian Collaboration in Quantum



Key Milestones in the History of Quantum Technology in India



2024-25

DEC 2023

QETCI Quantum Value Chain report launched. Report later included in the WEF Quantum Economy Blueprint as a best practice

JAN 2024

NQM launches call for preproposals for WG and T-Hubs

FEB 2024

National Quantum Mission Brainstorming session to take inputs from all Ecosystem stakeholders

APR 2024

200 KM QKD demonstration by QNu Labs (qbit error rate <3%) and Quantum AI Global 1st room temperature QMemory

JUL 2024

The QUAD Investors Network launches report on "Quantum Science and Technology in the QUAD Nations- Landscapes and Opportunities"

AUG 2024

Call for Proposals for startup funding under NQM

- DRDO's DYSL-QT, TIFR, and TCS's successfully test 6-qubit superconducting processor

OCT 2024

T-Hubs announced

NOV 2024

MoU Signed between NIELIT (MeitY) organization and QETCI for skill development in Quantum

One nation one subscription launched, providing country-wide access to research articles publications

DEC 2024

8 startups awarded grants as part of the new policy for funding quantum startups

Undergrad minor programs in Quantum launched by DST and AICTE

FEB 2025

Union Budget 2025 allocated ₹600 crore to NQM

MAR 2025

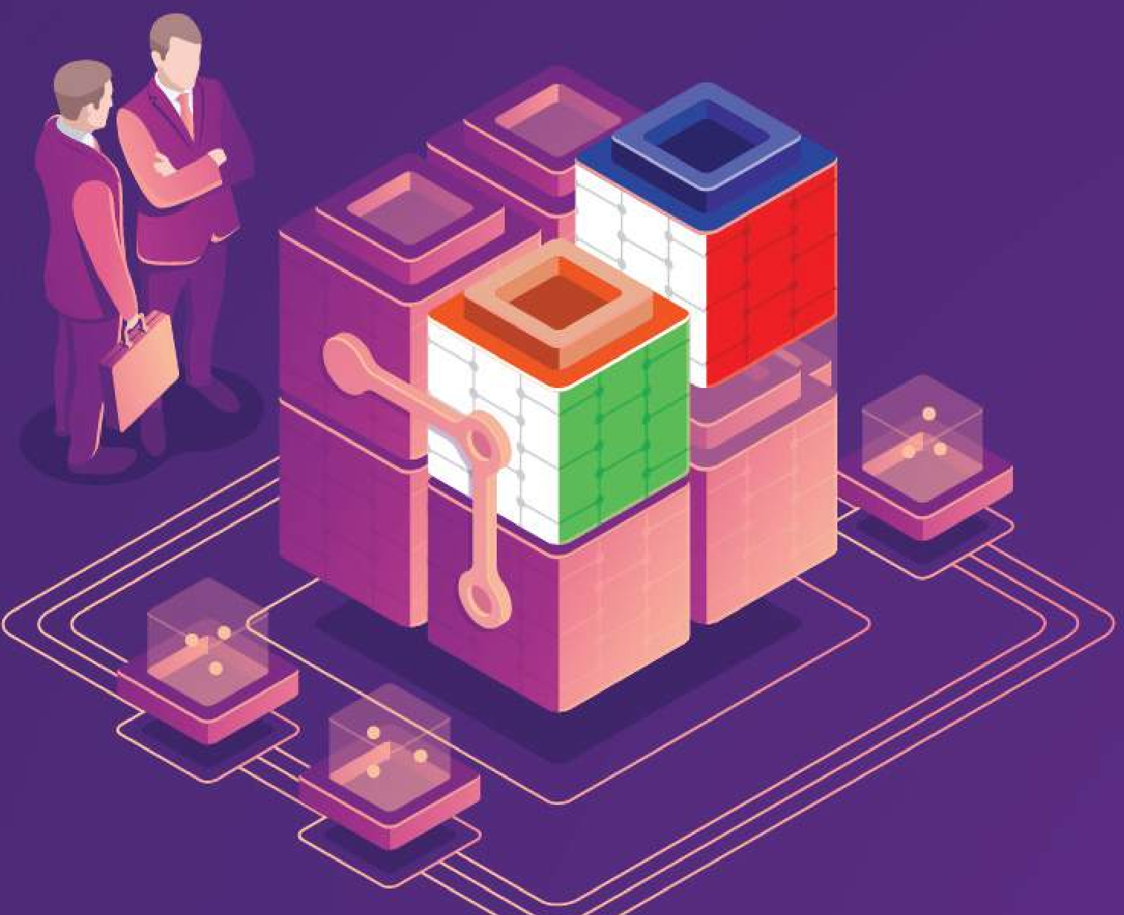
N ITI Aayog announces Frontier Tech Hub and releases paper on national security implications of QComp

APR 2025

QpiAI launches 25 Qbit Superconducting Qcomp

QNu Labs launches QShield™

Office of the Principal Scientific Adviser unveils India's International Technology Engagement Strategy for Quantum



5
India-Netherlands Bilateral Relationship

The year 2025 marks 78 years of the establishment of diplomatic relations between India and the Netherlands. From early collaborations in agriculture and water management, the relationship has evolved to span a broad spectrum—covering science, innovation, education, deep technology, and quantum science and technology. Indo-Dutch ties have matured into a robust partnership characterized by deep economic ties, strong political alignment, and collaborative innovation. The Netherlands stands as India's fourth-largest trading partner and investor in Europe, with bilateral trade encompassing a diverse array of goods and services.

A milestone in this evolution was the Virtual Summit on April 9, 2021, where both Prime Ministers underscored the need for coherence in strategic priorities, stronger public-private partnerships, and greater connectivity between innovation ecosystems. They acknowledged the growing significance of Key Enabling Technologies—such as artificial intelligence, cybersecurity, and quantum technologies—in addressing societal challenges and driving economic growth.

Subsequent high-level engagements, including President Ram Nath Kovind's 2022 state visit to the Netherlands and the 2024 Modi–Schoof dialogue, reinforced these themes. Innovation-led growth in areas like geospatial mapping, clean energy, and quantum science became focal points of a forward-looking bilateral relationship.

Deepening Technology and Economic Ties

Economic cooperation between India and the Netherlands has laid a strong foundation for deep-tech collaboration, including in quantum technologies. More than 300 Dutch companies operate in India, mirrored by a similar number of Indian enterprises in the Netherlands, underlining the deep commercial engagement between the two nations.

The Netherlands is India's fourth-largest European trading partner and a key source of FDI. Key exports from India include petroleum products, telecom equipment, pharmaceuticals, and electronic goods. Imports from the Netherlands feature high-tech items such as scientific instruments and advanced machinery, reflecting complementary industrial strengths.

The 2022 bilateral Fast-Track Mechanism (FTM), initiated by Department for Promotion of Industry and Internal Trade (DPIIT) and the Embassy of the Netherlands, aims to streamline Dutch investment into Indian strategic sectors, including high technology and R&D. Industry associations such as the Netherlands India Chamber of Commerce and Trade (NICCT), which expanded into India in 2023, and Chamber India in Amsterdam, foster deeper private-sector collaboration, investor-government dialogue, and establish a favourable business environment.

These economic frameworks—combined with mutual investments in sectors like semiconductors and photonics—strengthen the economic undercurrents needed for long-term quantum collaboration.

Evolution of Science, Technology, and Innovation (STI) Collaboration

Recent years have also seen heightened focus on emerging technologies including quantum, AI, cybersecurity, green hydrogen, and semiconductor technologies, underscoring their strategic significance in the bilateral STI agenda. STI cooperation between India and the Netherlands has matured through structured institutional frameworks:

- **2008 MoU on STI:** Signed in 2008 between the Dutch Ministry of Economic Affairs and Climate Policy and India's Department of Science & Technology (DST), the MoU has underpinned joint research programs for over 16 years. It supports interdisciplinary consortia to strengthen the global impact of research.

- **WAH! Agenda:** Covers water, agriculture, and health, and has evolved to include areas like climate-smart agriculture and precision diagnostics. This bilateral knowledge and innovation agenda addresses societal challenges in critical sectors. Recent discussions between both the Prime Ministers underscored enhanced cooperation in these areas, with potential expansion into emerging technologies.

- **Joint Working Group (JWG) on STI:** Focuses on themes like semiconductors, green hydrogen, and cybersecurity, enabling strategic bilateral dialogue. The JWG facilitates bilateral discussions to identify and promote collaborative research and innovation projects. Part of broader institutional mechanisms, it aligns with mutual priorities.

- **EU–India Trade and Technology Council (TTC):** Launched in February 2023, the TTC is a critical forum for addressing issues related to trade, trusted technology, and security. It explicitly covers emerging domains like quantum technologies – mentioning quantum computing and quantum communication, cybersecurity, and semiconductor supply chains, offering institutional support for setting shared standards and fostering responsible innovation between India and EU member states like the Netherlands.

The Netherlands Organization for Scientific Research (NWO) continues to strengthen ties with key Indian science and technology institutions, including the Department of Science and Technology (DST), the Department of Biotechnology (DBT), and the Ministry of Electronics and Information Technology (MEITY). These partnerships span research domains such as life sciences, biotechnology, electronics, and emerging digital technologies—offering fertile ground for expanding future collaboration in quantum and enabling technologies.

Major funding instruments enabling STI collaboration include:

- **Globalstars (EUREKA Initiative):** The 2020 multilateral call supported R&D in water, health, and agriculture, forming a template for future tech partnerships. Globalstars facilitates joint industrial R&D projects between EUREKA countries, including the Netherlands, and India. Eligible consortia include innovative companies driving economic growth and addressing global challenges. While not quantum-specific, Globalstars supports enabling technologies that could extend to quantum applications.

- **NWO–DST Merian Fund:** Has supported joint research since 2008, including a 2023 call on flood and drought management. Its structure is conducive to future quantum-related themes.

- **Horizon Europe:** The EU's €93.5 billion research and innovation program (2021-2027) welcomes Indian participation. The EU and India co-fund 11 calls, with 6 open in 2024, covering health, digital technologies, and climate change. India has benefited from €452 million in funding over the past 11 years, including €60 million for joint projects on EV battery recycling, marine plastic litter, and waste-to-hydrogen. Current Cluster 4 calls, focusing on supporting digital infrastructure, offer opportunities for quantum collaboration.

- **Indo-Dutch #StartUpLink initiative:** Led by Startup India and the Dutch Embassy—enhances cross-border startup engagement in FinTech and enterprise technologies. While not quantum-specific, such platforms nurture innovation ecosystems conducive to future quantum entrepreneurship. It provides networks and pilot opportunities, indirectly supporting innovation ecosystems that could include quantum startups. While not a direct funding instrument, it fosters partnerships that may attract investment.

These instruments offer a solid base for long-term, interdisciplinary cooperation that can encompass quantum science. The Indo-Dutch Innovation Tech Summit 2025 at IIT Delhi celebrated 16 years of STI partnership, showcasing bilateral innovation in semiconductors, clean energy, materials science, and quantum research. The summit reinforced institutional momentum for sustained deep-tech engagement.

Collaborations in Allied Sectors: Foundations for Quantum Engagement

India and the Netherlands have forged meaningful collaborations in deep-tech and allied sectors that support the evolution of quantum science:

- **Space:** The ISRO–ESA partnership—leveraging the Netherlands' ESTEC hub—enables joint missions and tech exchange relevant to satellite-based quantum communications.

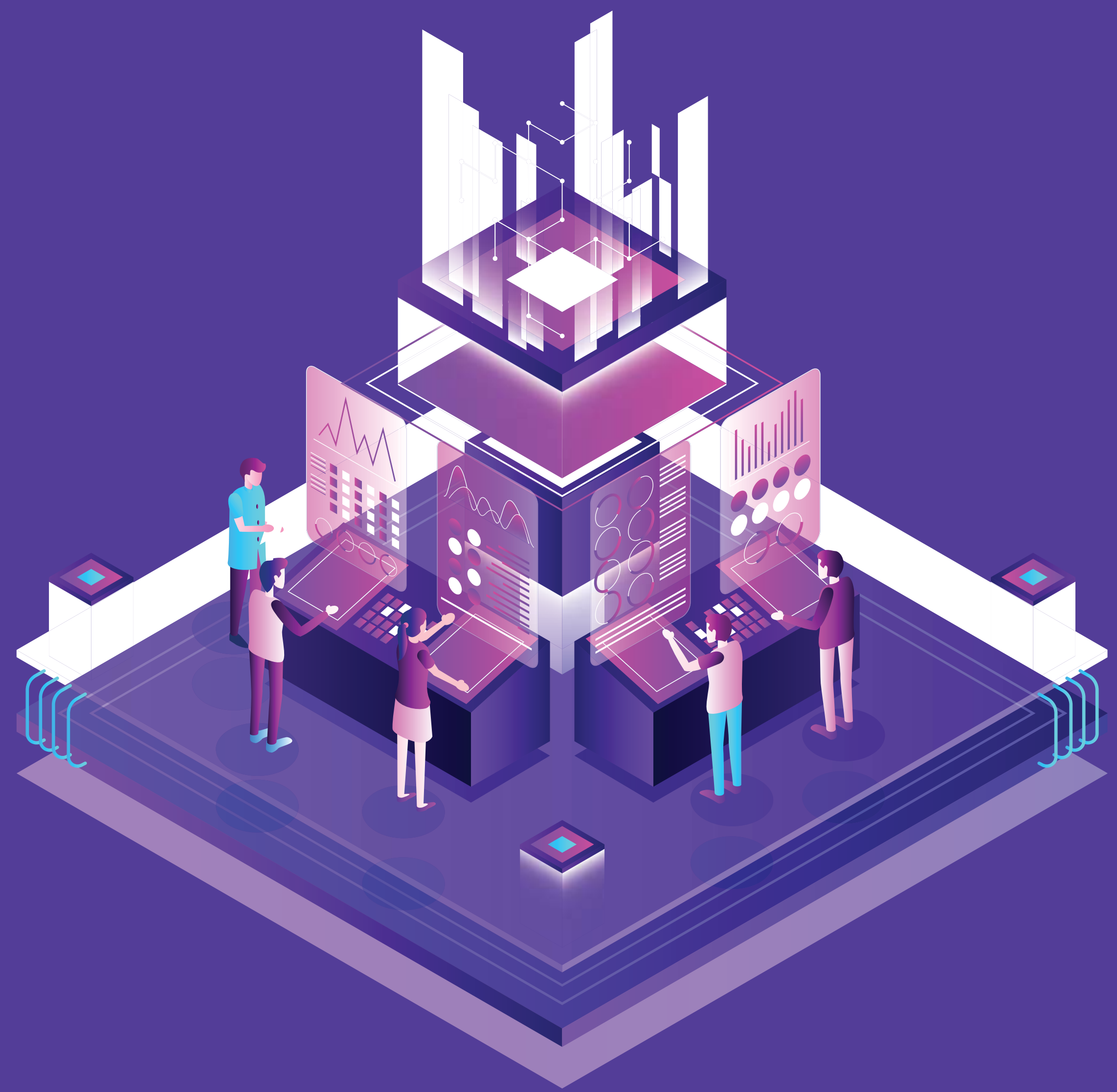
- **Cybersecurity:** Both countries prioritize quantum-resilient encryption. Dutch institutions and Indian firms like QNu Labs are exploring quantum-safe communication technologies.

- **Semiconductors and Photonics:** Collaborations under the EU–India Trade and Technology Council link Dutch photonic capabilities with Indian quantum hardware development.

- **Materials and Nanotech:** Shared research in advanced materials and nanotechnology underpins critical aspects of quantum device engineering.

- **Biotech and Health Tech:** Institutions like C-CAMP have hosted Dutch delegations to explore joint work in diagnostics and biophotonics—areas increasingly shaped by quantum sensing.

Together, these collaborations across space, security, health, and semiconductors provide the scaffolding for India and the Netherlands to scale up bilateral quantum science partnerships. The Netherlands and India share a dynamic and multifaceted partnership in Science, Technology, and Innovation (STI), with growing interest in quantum technology. Established frameworks, funding mechanisms, and strategic initiatives support this collaboration, aiming to address global challenges and foster innovation. The partnership is poised for further growth, particularly in a strategic area like quantum technology, which aligns with both nations' innovation priorities. While quantum collaboration is still in its formative stages, it is clearly emerging from a robust ecosystem of ongoing programs, research engagements, and institutional exchanges.



6 Stakeholder Analysis

The following chart shows the distribution of stakeholders across Industry, Academia, Public Sector and Government across different formats for gathering inputs.

1. In all formats of gathering input, the maximum inputs were from the industry, followed by the Academia.
2. The survey got the least engagement from amongst the stakeholders, most stakeholders seemed to prefer the 1:1 interview format for providing inputs.

Fig 16: Stakeholder distribution across input formats

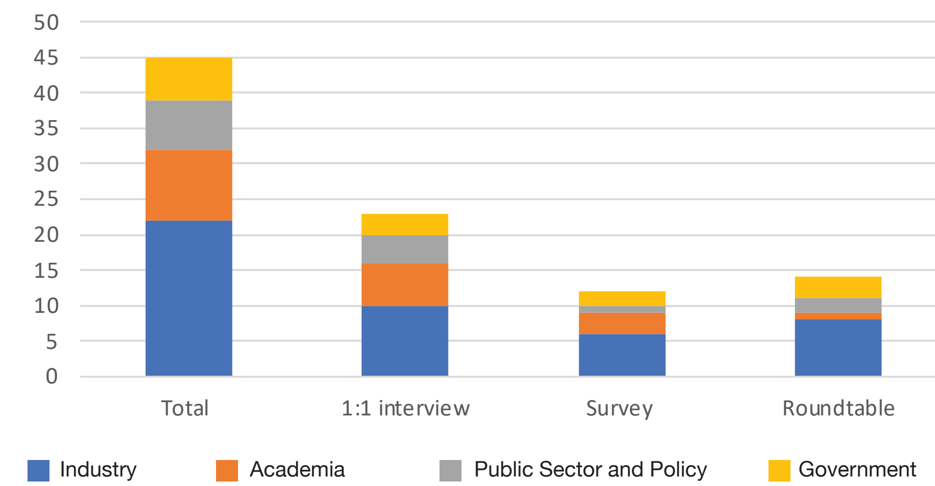


Fig 17: Netherlands Stakeholder Distribution

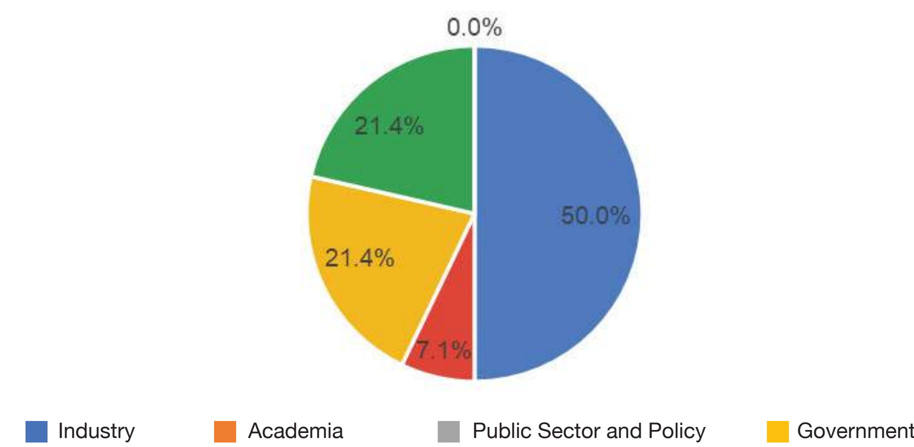
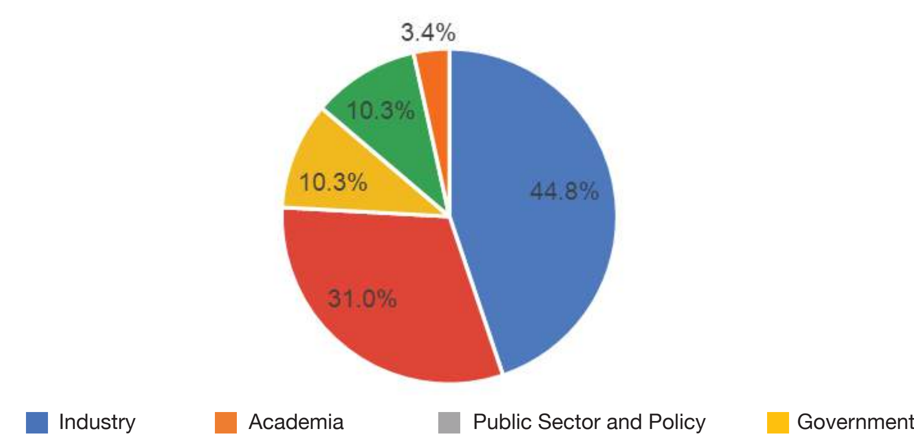


Fig 18: India Stakeholder Distribution



If we look at the relative distribution of stakeholders in Figure 17 and Figure 18 , we can see that there was almost equal interest within the Industry for Indo Dutch Collaboration in Quantum. On the other hand the interest within the Academia and Research community on the Netherlands side was pretty low. This was also corroborated with the kind of recommendations that came up for Collaboration areas between both countries.

Fig 19: Perceived challenges for collaboration in quantum between India and Netherlands stakeholders

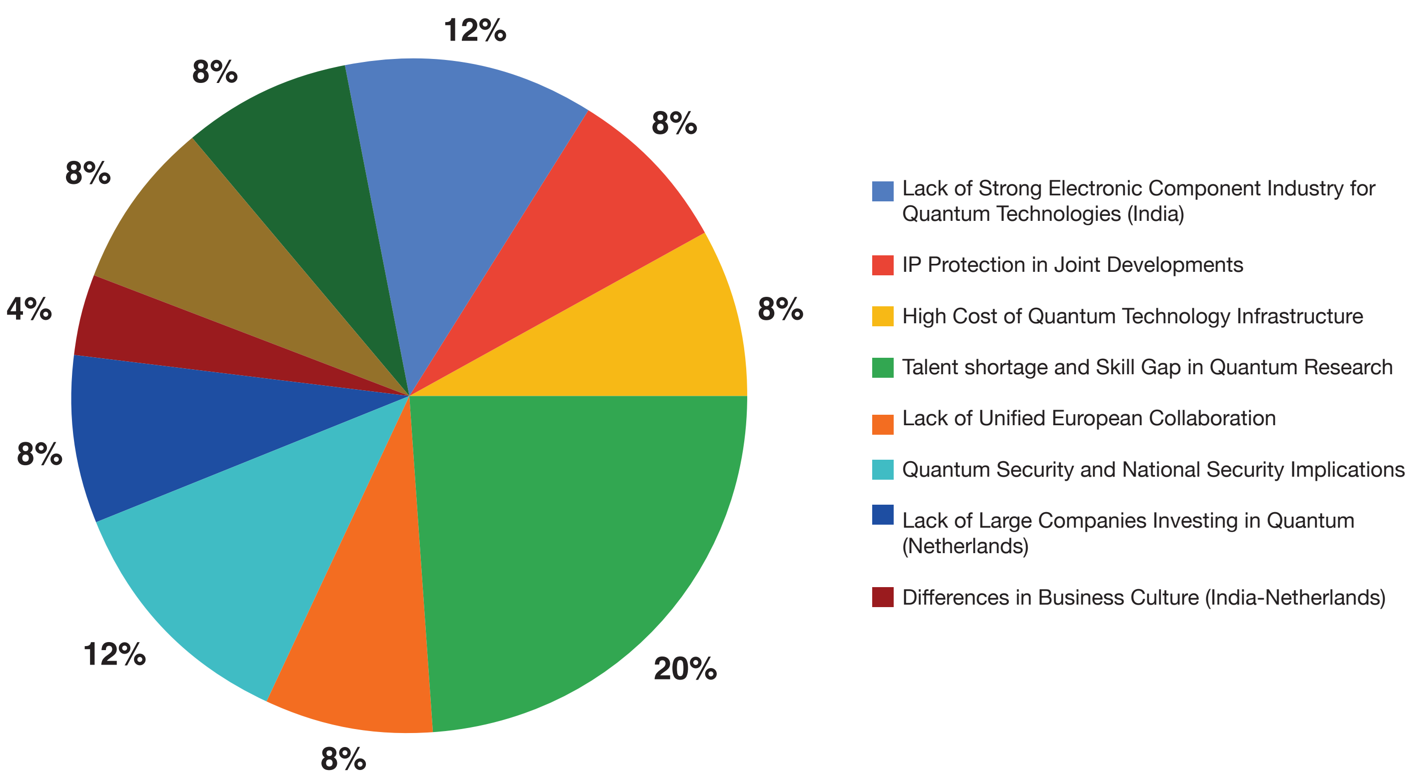
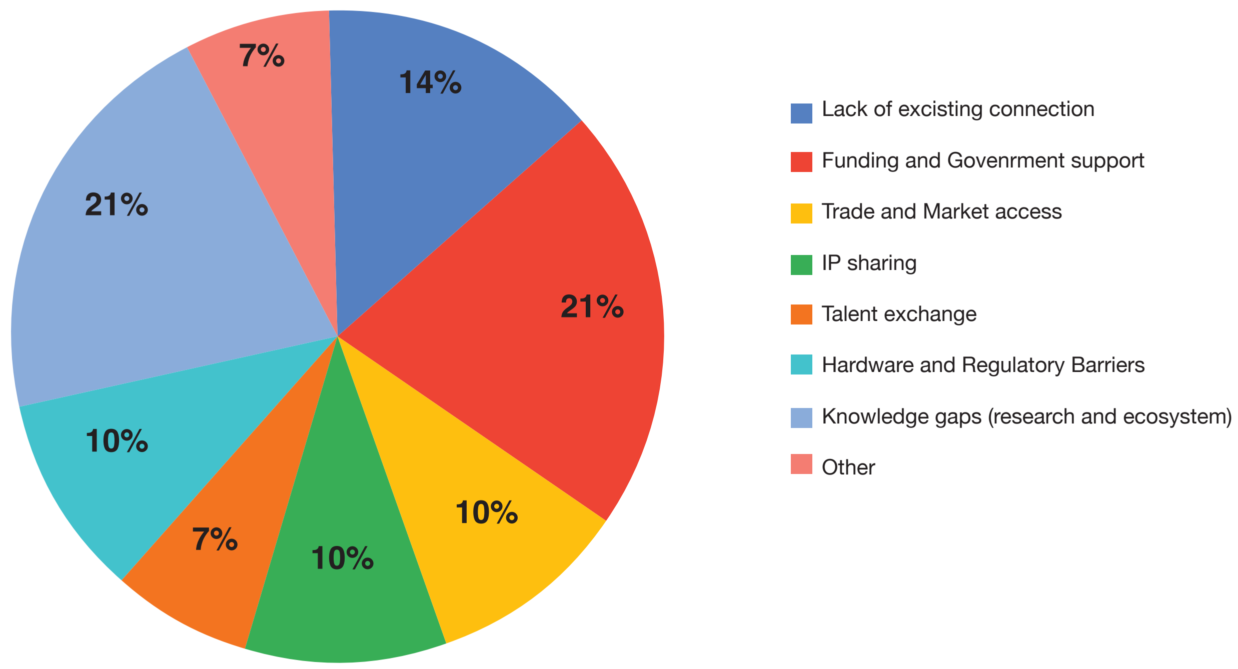


Fig 20: Perceived challenges for collaboration in quantum between India and Netherlands; Indian stakeholders



Challenges Identified

Below is a consolidated summary of the key existing or future challenges in India–Netherlands collaboration on quantum science and technology:

1. Geopolitical & Policy Concerns

- **Data Privacy & Security**
  Differing national laws and requirements for secure data handling could complicate joint projects.

- **Geo-political Tensions**
  Broader international relations may influence technology transfer and investment decisions. While tech sovereignty and security are crucial, too much emphasis on them may stifle innovation as well as collaboration, which thrives on open scientific collaboration and diverse talent pools.

- **Dual Use Technology**
  Quantum technology, particularly hardware, faces security constraints, making collaboration tricky due to dual-use technology concerns (civil and military).
- Since quantum technology has national security implications, discussions on collaboration often need involvement of national security teams.

- **Regulatory Frameworks**
  Developing or harmonizing regulations, policies, and standards for quantum tech remains a hurdle.

- **Standardization & Ethical Concerns**
  There is a lack of standardization in emerging quantum technologies. Ethical concerns, such as data privacy and integrity, are inhibiting the adoption of quantum technology, with many worried about its societal impacts.

2. Administrative & Diplomatic Barriers

- **Administrative Interest / Political Will**
  Collaboration may stall without strong governmental support or alignment of priorities. The imbalance between the small size of the Netherlands and the larger scale of India, which may result in a limited pool of participants from the Netherlands. Collaboration can only happen if the two governments make it a strategic bilateral priority.

- **Bureaucracy & Agreements**
  Absence of robust agreements (MoUs, treaties) and potential constraints (e.g., Make in India clauses) can impede technology transfer and joint ventures.

3. EU Collaboration Focus

The European Union is making efforts to ensure supply chain robustness and consistency. However, there is a tendency for EU countries to focus inwardly, which hinders collaboration with non-EU countries, such as India.

4. Lack of Indian Representation in Europe

While EU countries have science and innovation attachés in India, India lacks similar representation in Europe, limiting India's visibility in the European scientific ecosystem.

5. Resource Allocation & Funding

- Successful collaborations have typically involved a shared pot of funding. Independent funding models, where each side has its own resources, have proven ineffective and frustrating. There is a need for substantial and timely funding to facilitate effective collaborations, especially in enabling researchers to work across borders.

- The Dutch approach to funding and scaling is slower and more cautious compared to Silicon Valley's more aggressive and well-funded model. In the Netherlands, challenges include a lack of large companies actively investing in quantum technologies and limited public funding compared to other European countries like France and Germany. Scaling quantum startups is also difficult.

- Indian deep tech Investor community has starting investing in Quantum in the last year, however scaleup is required. Indian funding is also slower and more cautious compared to Silicon Valley .

- The public funding structures in the Netherlands are not as favorable as those in other European countries like France or Germany. Additionally, many of these funds do not allow collaboration with Indian entities, creating barriers to cross-border collaboration.

6. Awareness and Engagement

- A significant gap exists in awareness about companies and startups in both India and the Netherlands. While the Netherlands has a strong trade relationship with India in other areas, there is much to be discovered and developed in terms of collaboration, especially in deep tech and quantum sectors.

- Unlike collaborations between India and other countries like the US, UK, and Australia, the India-Netherlands partnership, particularly in quantum technology, is relatively nascent with minimal existing connections or joint projects.

- There is a lack of a dedicated platform or network that allows for easy identification and engagement with relevant companies and startups in the quantum technology sector. This gap hinders potential collaborations and the sharing of resources and knowledge.

7. Ecosystem & Multi-Stakeholder Coordination

- **Complex Collaboration**: Aligning academia, industry, and government goals in both countries can be challenging.

- **Implementation Gap** Translating joint research into market-ready solutions requires well-coordinated efforts and clear roadmaps.

8. Intellectual Property (IP) & Technology Transfer

- **Protecting IP:** Ensuring fair distribution of proprietary technology, patents, and research outcomes can be difficult. IPsharing is a key issue, especially for emerging technologies with commercial and strategic implications. Both sides need clear policies on IP pooling and joint ownership in quantum research collaborations. This issue is especially important in strategic sectors where both countries may restrict the sharing of certain quantum technologies

  A major concern in joint developments between the Netherlands and India is the protection of intellectual property (IP). There is a need for clear IP policies in collaborative projects.

- **Access to Advanced Tech:** Potential restrictions on sharing high-end technology or foundry capabilities, especially if these are tied to agreements with other nations.

9. Talent & Skill Gaps

- **Acquiring / Retaining Experts**: Quantum science demands highly specialized expertise, and competition for talent is global.

- **Bridging Technological Gaps**: Differences in R&D maturity between the two countries need to be addressed to collaborate effectively.

- **Talent Shortage**: There is a significant skill gap in quantum research, with neither India nor the Netherlands having sufficient talent to meet the growing demand.

10. Hands-On Collaboration Needs

For hardware and deep-tech collaboration, there is a recognized need for more in-person exchanges, but there is a lack of structured programs or agreements to facilitate this level of interaction between the two countries.

11. Challenges in Technology Scaleup

Both Indian and Dutch startups face similar challenges in deep-tech sectors like quantum, particularly in finding early adopters willing to take risks. Funding is available in both regions, but market enthusiasm and collaboration opportunities are key to scaling. Unless addressed through the Collaboration this could become a problem that makes collaboration slow and ineffective.

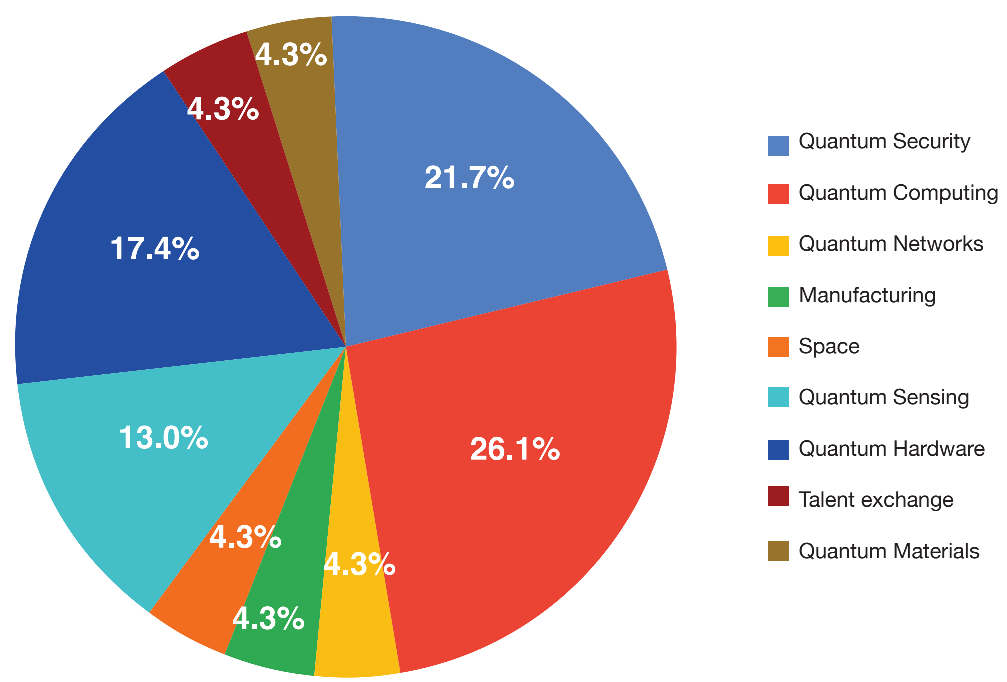
12. Culture Gap

- There is a cultural gap in how entrepreneurship, particularly in the physics and quantum space, is viewed in the two countries. The Netherlands has focused heavily on fostering startups, while in India, quantum innovation may still be more closely tied to academic institutions.

- This culture may be beyond entrepreneurship and could form a barrier to better understanding and collaboration.

Potential obstacles to collaboration revolve around political and administrative alignment, funding, IP protection, and coordinating diverse stakeholders. Nevertheless with well-structured agreements, investment, and a shared vision, India–Netherlands quantum collaborations can overcome these barriers.

Fig 21: Proposed areas for collaboration in quantum between India and Netherlands; Netherlands stakeholders perspective



Opportunities Identified

1. Priority Quantum Technologies

- **Quantum Computing**: India seeks collaboration to strengthen its relatively weak quantum computing ecosystem.
- **Quantum Communications**: Despite security sensitivities, opportunities exist—especially as standards mature.
- **Repeaters & Emitters**: Both countries are in early R&D stages, making these areas ripe for shared exploration.
- **Quantum Error Correction**: India's work is nascent; collaboration with Dutch experts could accelerate progress.
- **Focus on Post-Quantum Cryptography (PQC)**The Netherlands is keen to collaborate with India on PQC and broader quantum ecosystem initiatives, given the global security sensitivities around hardware development.
- **Global Challenges**: Both sides see quantum technologies (including PQC) as a means to tackle worldwide issues like climate change and migration.

2. Academic & Research Collaboration

- **Joint Programs & Exchanges**: Potential for dual-degree programs, student/faculty exchanges, and shared research projects
- **Curriculum Alignment**: Integrating industry-relevant quantum applications into academic courses remains a pressing need.
- **Access to Dutch Infrastructure**: Indian researchers could benefit from the Netherlands' photonics foundries and advanced fabrication facilities (e.g., in Delft).

3. Market & Tech Complementarity

- **India's Manufacturing Potential**: India can offer cost-advantaged production of components; the Netherlands provides high-end tech and specialized expertise.
- **Photonics & Chip Development**: The Netherlands' photonics ecosystem (e.g., Photonics Delta) could support Indian startups focused on photonics, leveraging the components India has strong research and talent base in photonics, which could be useful for Netherlands
- **India as a Consumer Market**: India's large population and demand for cost-effective solutions (e.g., in healthcare) provide a prime testing ground for quantum sensing pilots.
- **Netherlands' Tech Strength**: Dutch entities focus on hardware, photonics, and advanced R&D; India's software, computer science, and systems integration capabilities can fill critical skill gaps.
- **Netherlands as Gateway to Europe**: Although the Dutch market is relatively small, it can open doors to broader EU collaborations.

4. Talent Shortage & Exchange

- **Bridging Skill Gaps:** The Netherlands faces a shortage in quantum/photonics; India has a large talent pool in computer science and coding.
- **Reciprocal Exchanges**:n Ensuring two-way mobility of researchers, students, and professionals to avoid a one-sided outflow. Structured exchange programs for young professionals and students are viewed as key to building a robust talent pipeline.
- **Long-Term Partnerships**: Structured programs (Startup Visa, academic collaborations) can lay the groundwork for sustained cooperation.

5. Sector Opportunities

- **Computing & Communication**: Less sensitive than defense or dual-use sensing, making these areas prime for cross-border R&D.
- **Quantum Photonics & Integrated Circuits**; A major mutual interest, as photonics becomes integral to future semiconductor and quantum devices.
- **Quantum Software & Integration**: Indian system integrators (e.g., Tech Mahindra) could support Dutch hardware innovations, mirroring existing collaborations with U.S. tech giants.
- **Quantum Networking**: : Strong Dutch capabilities (e.g., at Delft) and growing Indian expertise could combine to advance quantum internet initiatives.
- **Quantum Algorithms & Machine Learning:** Currently no active India–Netherlands links, but recognized as an emerging area.
- **Photonic Devices & NV Centers**: Indian researchers see potential in integrating advanced Dutch photonic systems with nitrogen-vacancy (NV) technology.
- **Cybersecurity & PQC**: Knowledge-sharing on PQC algorithms, security engineering, and certification processes can help both nations tackle global data protection concerns.

6. Industry Collaboration & Ecosystem Building

- **Public–Private Partnerships**: Combining Indian system-building prowess (e.g., TCS, Tech Mahindra) with Dutch research hubs could accelerate product development.
- **Innovation "Roadshows"**: Joint events showcasing each nation's quantum ecosystem can uncover mutual interests and partnership opportunities.
- **Quantum-Focused Incubators & Events**: India's proposed 2025 international quantum event and quantum innovation hubs (e.g., in Hyderabad) can welcome Dutch participation.
- **Academia-Industry Synergies**: Deeper partnerships between universities and private sectors in both nations can accelerate development.

7. Emerging Ecosystem Platforms

- **Quantum-Focused Incubators:** Proposed hubs in Indian cities (Hyderabad, Bangalore) could foster early-stage R&D and startups in quantum technologies.
- **Test Centers & PQC Guidelines:** Both countries could benefit from jointly established facilities offering testing, certification, and guidelines for PQC adoption across critical infrastructure.

8. Governmental Role & Geopolitical Context

- **Increased Government Investment**: Despite geopolitical shifts (e.g., post-Ukraine war), both governments remain committed to funding quantum R&D.
- **Quantum Security & Defense**: A high-priority area with potential for rapid growth, underscoring the need for clear security policies.
- **Bilateral R&D Programs**: Developing dedicated India–Netherlands programs is seen as essential to advance joint quantum research and applications.

9. Industry Perspectives & Incentives

- **Tax Benefits & Foreign Talent Attraction:** The Netherlands provides tax incentives that Indian companies can leverage by setting up local offices, benefiting from a culturally diverse workforce.
- **Sector-Specific Use Cases**
- **Telecommunications:** Quantum may open new revenue streams.
- **BFSI**: Quantum-based fraud detection and AML solutions.
- **Manufacturing & Aerospace**: Predictive maintenance and optimized design.
- **Space**: Potential partnerships through the Netherlands' involvement in the European Space Agency.

10. Infrastructure & Supply Chain Gaps

- **India's Electronic Components Industry:** Currently not as developed for: quantum-grade hardware, whereas the Netherlands hosts specialized suppliers like QPI.
- **Chip Testing & Specialized Processes**: The Netherlands' expertise could complement India's need for advanced testing capabilities, bridging a critical industry gap.
- **Indigenous Quantum Systems**: India's push for homegrown quantum solutions can be bolstered by Dutch R&D partnerships.

- **Certification & Standards** : Collaboration in security certifications (e.g., Common Criteria, FIPS) and possibly establishing joint certification labs to streamline cross-border market access.

11. Growth & Market Expansion

- **Entry into Europe:** Leveraging Dutch credibility and infrastructure helps Indian startups gain traction in EU markets.
- **Scaling Hardware & Software**: Collaboration addresses hardware R&D needs in the Netherlands while utilizing India's strong software expertise.
- **Cost-Effective Manufacturing:** Establishing business in India by the Dutch quantum component manufacturing companies can benefit Dutch companies seeking competitive pricing.

12. Overall Collaboration Potential

- **Mutual Strengths**: India offers software scalability and a large talent pool; the Netherlands brings deep hardware and photonics expertise.
- **Cybersecurity Synergy**: PQC and quantum-based security solutions align with growing global data privacy concerns.**Long-Term Outlook**:
- Building a quantum-skilled workforce, fostering ecosystem partnerships, and developing robust funding and regulatory frameworks are vital next steps.

Overall, the India–Netherlands quantum collaboration conversation emphasizes joint research, infrastructure development, manufacturing synergies, talent exchange, and the potential for each country to leverage the other's strengths—India's scale and software expertise, and the Netherlands' advanced quantum R&D and photonics ecosystem. It also points out opportunities in PQC hardware-software integration, and strategic partnerships.

There is a strong interest from the Netherlands in collaborating with India on post-quantum cryptography (PQC) and quantum ecosystem development.

While quantum hardware may have limitations due to global security concerns, there is enthusiasm for collaboration on PQC and ecosystem-related efforts.

India as a potential consumer market for quantum sensing technologies, while the Netherlands focuses on technology development. Collaboration in India could help mainstream adoption, especially due to the large population and demand for cost-effective healthcare solutions. pilot programs in India to explore how quantum sensing can solve major problems in healthcare and drug development. They are particularly interested in collaborating with pharma and biotech companies in India that face challenges not solvable by conventional methods.

India's strength in computer science and software development could complement the Netherlands' focus on hardware, providing a balanced partnership. There's potential for India to support the Netherlands in quantum software development, where the U.S. currently dominates with major players like IBM and Microsoft.

Indian system integrators (such as Tech Mahindra) are already active in quantum technology globally, and there is an opportunity for them to partner with Dutch companies, particularly in consulting and quantum security solutions.

India's growing research excellence in quantum technologies positions it as both a contributor to and a beneficiary of international collaborations like those promoted by the Global Forum on Cyber Expertise (GFCE).

The Netherlands is open to knowledge-sharing and collaboration in quantum research, especially in ecosystem-related areas, while understanding the limitations related to security. Dutch institutions like TNO (Netherlands Organisation for Applied Scientific Research) are key players in these potential collaborations.

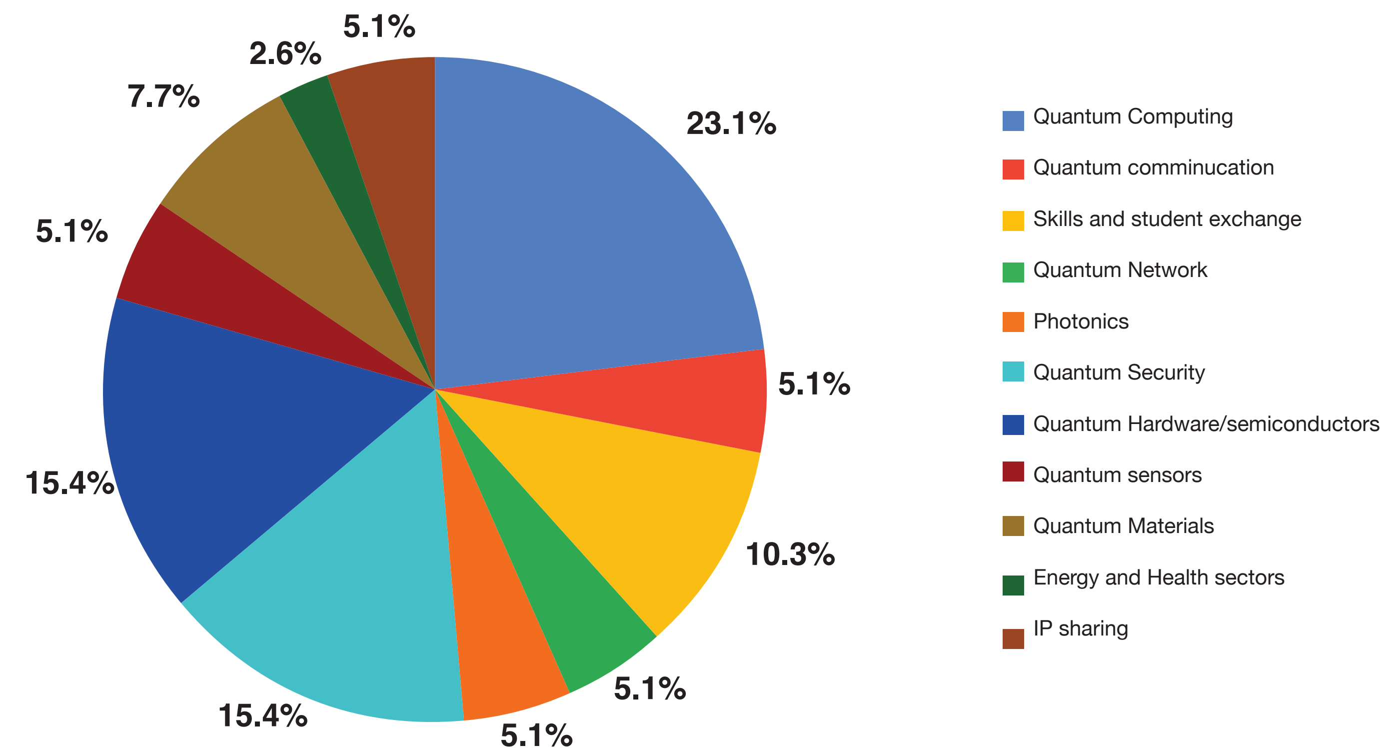
The geopolitical landscape has shifted, particularly post-Ukraine war, which has impacted trust and international collaboration in emerging technologies.Despite these challenges, both parties emphasize the need for cooperation to address global challenges like climate change and migration, for which quantum technology could play a role

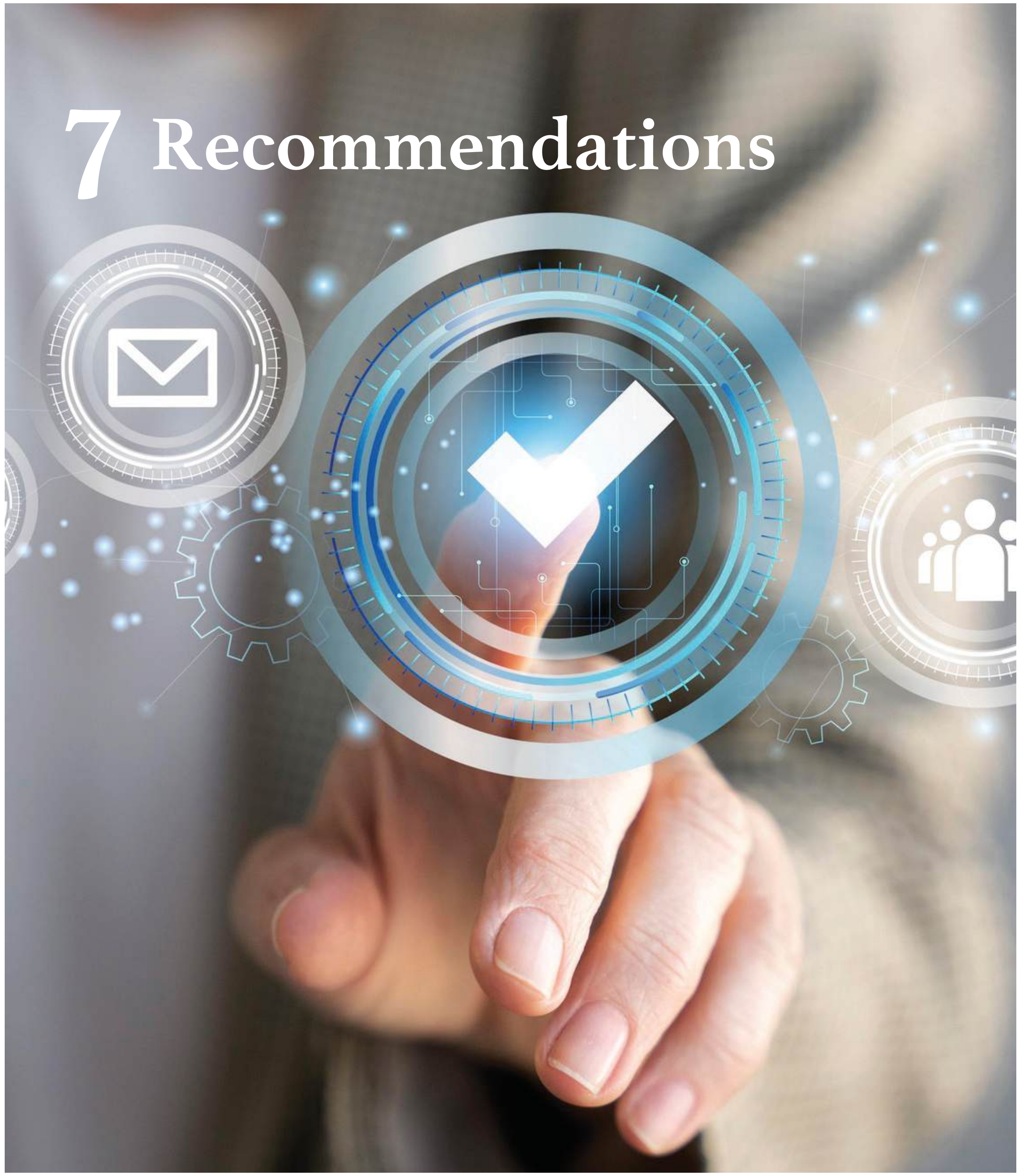
A significant portion of the Dutch tech workforce is of Asian origin, creating opportunities for cross-border collaboration. Companies like Tech Mahindra think of this as a great opportunity

From a IT services industry perspective potential areas for India-Netherlands collaboration include:

- **Telecommunications:** Quantum technology could address the need for new revenue models.
- **BFSI**: Quantum could improve fraud detection and anti-money laundering efforts.
- **Manufacturing**: Quantum computing could predict equipment failures in aerospace.
- **Space**: Collaborating with the Netherlands in quantum technology for space missions, given its significant role in the European Space Agency.

Fig 22: : Proposed areas for collaboration in quantum between India and Netherlands; India stakeholders perspective





This chapter presents a structured framework to advance India–Netherlands collaboration in quantum science and technology through joint research, innovation, and knowledge-sharing. It begins by identifying key opportunities for collaboration—derived from stakeholder interviews, ecosystem analysis, and national strategies—which highlight areas with high potential for mutual benefit and ecosystem-wide impact. These opportunities form the foundation for deeper cooperation and serve as a practical guide for building long-term partnerships. The subsequent section provides strategic recommendations and investment priorities, offering targeted, actionable instruments for stakeholders to formalize these identified opportunities for collaboration, support cross-border growth, and align efforts with each country's policy and ecosystem priorities.

Fig 23: Opportunities for collaboration between ecosystems

This chapter presents a structured framework to advance India–Netherlands collaboration in quantum science and technology through joint research, innovation, and knowledge-sharing. It begins by identifying key opportunities for collaboration—derived from stakeholder interviews, ecosystem analysis, and national strategies—which highlight areas with high potential for mutual benefit and ecosystem-wide impact. These opportunities form the foundation for deeper cooperation and serve as a practical guide for building long-term partnerships. The subsequent section provides strategic recommendations and investment priorities, offering targeted, actionable instruments for stakeholders to formalize these identified opportunities for collaboration, support cross-border growth, and align efforts with each country's policy and ecosystem priorities.

1. Opportunities for Collaboration:

To build stronger ties between the Indian and Dutch quantum ecosystems, it is essential to invest in structured platforms that foster mutual understanding, increase visibility, and enable sustained engagement. This section outlines key avenues for collaboration with the potential for wide-ranging ecosystem impact, offering a foundation for deeper scientific, industrial, and strategic partnerships.

1.1. Awareness, Showcase, and Networking Sessions

Indian and Dutch stakeholders identified limited mutual awareness of ecosystems and capabilities, lack of deep institutional connections, knowledge gaps, and differences in business culture as key challenges to effective engagement and collaboration.

A dedicated **matchmaking day**, modelled on the successful EU-India Matchmaking Event and Dutch-German

Matchmaking Day, could bring together researchers, industry leaders, and other key stakeholders. These events enable quantum companies, startups, research institutions, and policymakers from both countries to showcase their ecosystems, capabilities, and innovation priorities. Matchmaking days should emphasize ecosystem discovery and early-stage networking, laying the groundwork for deeper technical engagements through joint R&D initiatives, knowledge-sharing platforms, and sector-specific collaborations.

Quantum showcases for both nations' quantum ecosystem can uncover mutual interests and partnership opportunities. Dedicated sessions highlighting local innovations from India and the Netherlands within a global context, and international quantum conferences, would help attract international interest and investment, especially for emerging players. To move beyond primarily government-led efforts, it is essential to actively involve the private sector. A more inclusive approach will enable holistic ecosystem development and ensure that quantum collaboration delivers broader and lasting impact.

Additionally, innovation **roadshows** would raise the global profile of both countries' quantum efforts. Such roadshows would serve as springboards for developing trust, visibility, and shared understanding, paving the way for joint ventures and collaborations—particularly among early-stage startups and SMEs seeking international partnerships.

Regular facilitation of **industry networking events** can further foster informal, trust-based engagement among ecosystem stakeholders. These forums would support dialogue and provide valuable industry feedback to refine bilateral initiatives. Unlike formal showcases, such gatherings encourage iterative conversations that often lead to deeper, more sustainable collaborations, joint learning, and knowledge-driven development.

By institutionalizing these engagement mechanisms and ensuring regularity and inclusivity, India and the Netherlands can establish a strong foundation for sustainable quantum technology partnerships.

1.2. Education and Talent

India and the Netherlands have a unique opportunity to build a globally competitive quantum workforce through structured, reciprocal educational and talent partnerships. QST is inherently interdisciplinary and rapidly evolving, necessitating international cooperation to cultivate a workforce capable of addressing both current and future challenges. By enabling students, researchers, and faculty members to engage with institutions abroad, both countries can foster the next generation of quantum professionals and innovators who are globally aware and technically proficient. Structured exchange programs, embedded internships, and collaborative research initiatives will help ensure that talent development remains aligned with innovation demands across both ecosystems.

A key focus of India–Netherlands cooperation should be on the **development of academic curricula and programs** that integrate real-world quantum applications. These programs will better align education with industry needs, while also fostering knowledge-sharing and innovation diffusion. This ensures that graduates are prepared not only for academic careers but also for roles in global startups, national laboratories, and private sector R&D units. The inclusion of real-world use cases—spanning quantum hardware, software, and communication—will enrich learning and promote applied innovation.

Structured **student and faculty exchanges** are central to this effort. These should be reciprocal, ensuring balanced flows of talent, mutual benefit, and shared learning. For example, Indian students and researchers could benefit from the Netherlands' expertise in quantum hardware and photonic technologies, while Dutch students could engage with India's growing capabilities in quantum algorithms, software development, and security protocols. Online courses, and remote internships and job opportunities could be explored to strengthen knowledge exchange and kickstart more intensive exchange and innovation between the ecosystems.

To make these collaborations sustainable, financial, and logistical barriers must be addressed. Governments and academic institutions should **allocate resources to subsidize travel, accommodation, and administrative costs.** Cost-sharing mechanisms and subsidized exchange programs would significantly increase participation, especially from early-career researchers and under-resourced institutions. In-person engagements can be complemented by virtual workshops and joint online modules to broaden access and continuity. These virtual initiatives can draw inspiration from successful Indo-Dutch capacity-building efforts, such as the Indo-Dutch Cyber Security School. Furthermore, **structured joint calls** for academia and research projects in fundamental QST can serve as effective platforms for sustained knowledge-exchange, laying the foundation for long-term institutional partnerships.

Building a globally competent and technically skilled workforce requires long-term investment and strategic coordination. The quantum sector faces a cross-border shortage of trained professionals. Alleviating this bottleneck will be crucial for the successful adoption of quantum technologies. A partnership model grounded in reciprocity, trust and respect, and long-term investment will ensure that India and the Netherlands not only share knowledge but also co-create the next generation of quantum innovators.

1.3. R&D and Innovation

India and the Netherlands can significantly benefit from a coordinated approach to both foundational and translational quantum research, particularly in quantum communication, photonics, quantum materials, and integrated quantum systems. A vibrant R&D partnership can catalyze innovation across the quantum value chain.

Quantum research is inherently interdisciplinary and collaborative, and fragmented markets and siloed efforts often lead to reduced market potential and supply chain inefficiencies. Coordinated bilateral collaboration is essential to overcome these limitations. Collaboration between the five Quantum Delta NL hubs and their counterparts in India's four Quantum T-Hubs and lead institutions can serve as the foundation for aligning broader research directions. This coordination should be complemented by the establishment of dedicated points of contact for specific research and innovation sub-streams to enable streamlined, goal-oriented collaboration and reduce fragmentation.

To strengthen research and innovation collaborations, **government-to-government collaboration** must be strengthened to facilitate smoother project implementation. Bilateral agreements that simplify joint project approvals, infrastructure sharing, and researcher and talent mobility are essential to reducing bureaucratic delays. These frameworks should also include mechanisms for technology transfer, certification, and export/import facilitation—especially for quantum technologies that are subject to stringent controls. Furthermore, coordinated government checkpoints can ensure security in sensitive projects can enable deeper collaboration and joint innovation projects.

Early-stage research domains such as quantum communications and networking—especially quantum repeaters, emitters, and memory—offer promising grounds for joint research. India's strengths in foundational research and software, algorithms, and scalable architectures complement Dutch capabilities in photonics, fabrication, and cryogenic infrastructure. Facilitating infrastructure access through bilateral agreements—for example, Dutch photonics foundries and Indian quantum software expertise—would accelerate joint innovation in quantum error correction, quantum simulation, integrated quantum systems, foundational QKD research, and nitrogen-vacancy (NV) and silicon vacancy (SiV) systems. Institutions such as IIT Hyderabad, IIT Madras, Raman Research Institute, IISc, and TU Delft, Leiden University, and Eindhoven University are well-positioned to lead these efforts, especially in quantum networking and communications. India's growing interest and investment in integrated photonics provide further synergy with Dutch priorities.

A **joint funding models** with clearly defined contributions, transparent governance, and shared intellectual outputs will incentivize sustained Indo-Dutch collaboration. It will ensure equitable investments, build trust, and facilitate the rapid launch of joint calls and pilot projects. Funding initiatives should prioritize proposals that build on existing collaborations and demonstrable deployments to drive tangible outcomes.

The application of R&D efforts should be guided by a use-case-driven innovation strategy. **Focused industry challenges and sector-specific collaboration** such as secure communication in banking and financial services, predictive maintenance in aerospace, and fraud detection in telecommunications can anchor research in real-world relevance and help both countries better understand practical deployment challenges and fine-tune their R&D efforts accordingly. These engagements can be structured through domain-specific working groups and policy roundtables involving industry, academia, and government.

This approach not only improves the likelihood of commercial adoption but also helps align research priorities with industry needs, thereby accelerating the time-to-market for emerging quantum solutions. To deepen the research collaboration and promote co-learning, joint technical workshops and research symposia must complement project-based partnerships.

1.4. Leveraging Complementary Strengths

India and the Netherlands have a strategic opportunity to collaborate in QST by aligning their complementary strengths. Each country brings distinct yet synergistic capabilities to the table, offering a strategic advantage when paired effectively.

India's expertise in quantum software, algorithms, low-cost engineering, and material production aligns well with the Netherlands' expertise in quantum hardware, photonics, and quantum network infrastructure. Together, these capabilities form a comprehensive innovation value chain that can accelerate progress and position both nations as influential players in the global quantum ecosystem.

With shortage of sustainable **quantum workforce** in the Netherlands in areas like photonics, enabling Indian talent in Dutch research institutions and startups would offer mutual benefits. India's vast and growing pool of quantum talent offers capacity support that can help Dutch institutions and startups scale their innovation efforts. While the Netherlands' deep strengths in quantum hardware, cryogenics, and photonic technologies offer a training and collaboration ground for Indian researchers. These models should be extended to other areas like quantum networking and secure communications, where both nations have strategic interests and technical capabilities.

India offers significant advantages for scaling quantum technologies through its dynamic startup ecosystem, cost-efficient engineering and manufacturing base, and large, rapidly growing domestic market. These assets make it an attractive partner for Dutch companies seeking to validate and commercialize innovations at scale.

Finding early adopters for quantum solutions is challenging globally. Access to each other's markets in quantum will enable access to increased pool of investors and users. Dutch startups, in particular, can benefit from partnering with Indian firms to overcome barriers in **market entry and product scaling**. India's strengths in marketing, services, and regulatory navigation—combined with its growing pool of quantum talent—can accelerate access to both Asian and global markets.

To deepen this collaboration, India and the Netherlands can explore v**ertically integration of quantum hardware supply chain.** India's potential as a large-scale manufacturing and component assembly hub complements the Netherlands' expertise in high-precision fabrication and quality certification. Such integration would enhance supply chain resilience, lower production costs, and reduce reliance on limited global suppliers.

Joint manufacturing partnerships should be supported by structured knowledge exchange—through collaborative labs, training modules, and component testing initiatives. These programs can ensure that quality and innovation standards are consistently met across both ecosystems.

When effectively coordinated, the India-Netherlands partnership in quantum can advance not just their economic and technological aspirations, but also contribute to the stability and diversity of the global quantum supply chain.

1.5. Knowledge-sharing

Knowledge-sharing is the connective tissue that binds together all other forms of bilateral engagement—whether educational, industrial, or policy-oriented. For India and the Netherlands, investing in structured and multi-tiered knowledge-sharing initiatives will not only enhance innovation capacity but also ensure that collaboration remains dynamic, inclusive, and future-ready.

Currently, limited awareness exists between Indian and Dutch researchers about each other's projects and ecosystem priorities, resulting in underutilized collaboration opportunities and misaligned proposals. To address this, both countries should support frequent **workshops, joint research symposiums, and thematic seminars**. These events, ideally organized on a quarterly or biannual basis, would provide platforms for deeper engagement on research themes prioritized by both nations such as quantum networking, quantum machine learning, and materials science.

Structured academic partnerships—supported through formal agreements enabling co-authorship, data sharing, and infrastructure access—can generate high-impact outputs and strengthen institutional relationships. Co-developing research on foundational quantum science offers a low-hanging fruit for deeper collaboration, while use-case-driven projects in sectors like BFSI, healthcare, and communications can demonstrate real-world impact and unlock commercial value.

A key gap in the Dutch ecosystem is the absence of **system integrators**—a space where Indian companies, such as Tech Mahindra, can contribute significantly. These firms can offer consulting, hardware integration, and **commercialization support**, helping Dutch startups bring solutions to market faster. Conversely, Dutch expertise in certification and precision engineering can support Indian commercialization efforts. Setting up certification labs in India with Dutch technical support and promoting knowledge-sharing in certification and testing can further fast-track product validation for global markets.

Equally important are strong **public–private partnerships** and knowledge-sharing platforms. These include industry-academia consortia, bilateral quantum innovation challenges, and sandbox environments for technology testing. Integrating feedback from end users—especially in finance, aerospace, and healthcare—into R&D cycles will help shape practical, high-impact quantum solutions, and could also lead to new revenue models.

To institutionalize collaboration, India and the Netherlands should establish a **joint digital knowledge hub**. This platform would serve as a centralized repository for ongoing projects, regulatory updates, open datasets, funding opportunities, and directories of quantum experts from both countries. India is also developing open-source indigenous quantum solutions such as Quantum Computer Simulator (QSim) toolkit which can form basis of collaboration with Dutch academic and research institutions. By streamlining access to key information, it would lower entry barriers, enhance transparency, and enable smoother collaboration among institutions, startups, and government agencies.

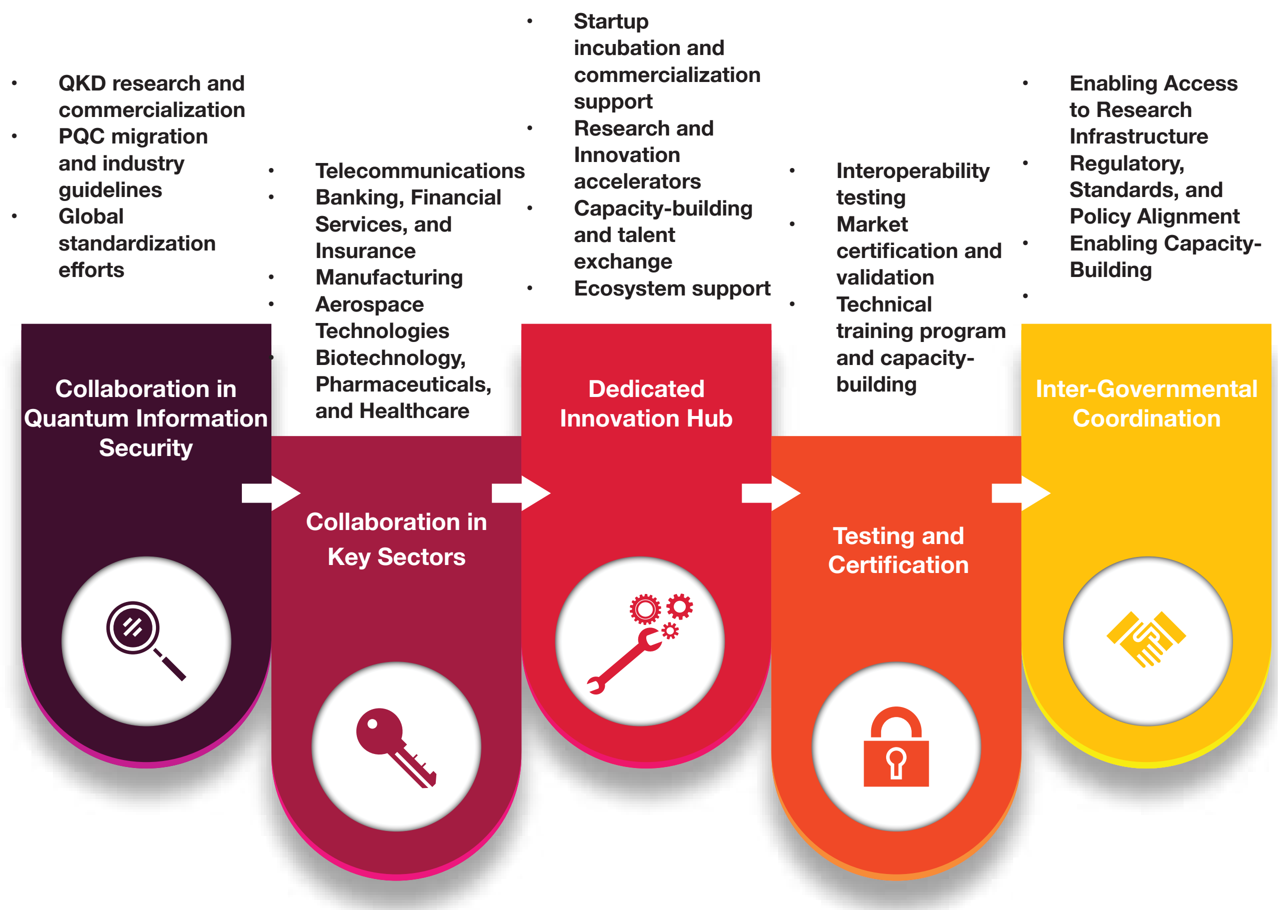
1.6. Intellectual Property Alignment

Despite robust innovation ecosystems in both India and the Netherlands, the absence of a shared IP framework tailored to quantum research poses a significant challenge to collaboration. This gap in IP management creates uncertainty around ownership, licensing, and commercialization rights—particularly in cross-sector projects involving both academia and industry—potentially deterring investment and undermining trust.

To address this, both countries should prioritize the development of a **comprehensive IP-sharing and technology transfer framework** that balances commercial interests with national security considerations. This framework should establish clear licensing norms, mechanisms for equitable revenue sharing, and protocols for joint IP creation. Early adoption of such guidelines is essential to prevent future disputes and to ensure that innovations are both protected and aligned with national security requirements. Additionally, **startups and SMEs should receive targeted support** through access to specialized legal expertise and soft-landing programs in each other's markets.

By jointly developing a clear and enforceable IP-sharing policy, India and the Netherlands can significantly enhance investor confidence and ensure that collaboratively developed quantum innovations are protected and commercialized in a fair and transparent manner.

Fig 24: Strategic Recommendations and Investment Prioritization



2. Strategic Recommendation and Investment Prioritization

To translate the promise of India–Netherlands quantum collaboration into measurable outcomes, this section outlines a clear, prioritized set of investment areas with the highest potential for impact. It emphasizes the need for streamlined, substantial, and timely funding, and proposes actionable strategies to formalize opportunities through targeted initiatives. The recommendations aim to guide Indian and Dutch stakeholders in operationalizing collaboration across research, industry, and policy domains.

2.1. Bilateral Collaboration in Quantum Information Security

Quantum information security, including both PQC and QKD, is rapidly emerging as a critical with significant implications for digital sovereignty, financial institutions, critical infrastructure, and national security. Advent of cryptographically-relevant quantum computers will break classical encryption and breach data security. There is a need to migrate from classical communication systems to quantum secure communications to ensure data security. Migration is not just a technical challenge but a complex societal and strategic challenge as well. Both Indian and Dutch stakeholders have expressed interest in collaboration in quantum information security.

Cryptographic Migration is a time-consuming and costly process which does not follow one-size-fits-all approach. Globally, countries have issued guidelines and frameworks to assist governments and businesses in transitioning to quantum secure communications through a hybrid approach that is agile and incorporates PQC, QKD, or both. Successfully navigating this transition requires close international cooperation, investment, skilled human resources, public-private collaboration, and careful risk assessment and planning.

India and the Netherlands have made notable progress in preparing for this shift. India's TEC has released provisional standards on Requirements for QKD and Quantum-secure cryptographic systems. India's technical reports and standards—such as those on PQC Migration, Quantum Random Number Generators (QRNG), and Quantum Secure 5G/Beyond-5G Infrastructure—complement the Netherlands' PQC Migration Handbook developed by TNO, CWI (Centrum Wiskunde & Informatica), and AIVD (The General Intelligence and Security Service). Both countries are actively testing interoperability and establishing guidelines and standards, highlighting a shared commitment to robust digital ecosystems.

Post-Quantum Cryptography (PQC) offers one of the most immediate opportunities for collaboration. India's strength in quantum talent base, software engineering, and emerging startups developing quantum-resistant algorithms can complement Dutch expertise in cryptographic protocol design, allowing the co-development of industry-ready PQC solutions for sectors like digital banking, public infrastructure, space, and healthcare.

Indian system integrators, already engaged in global quantum technology projects, can collaborate with Dutch companies—particularly in the areas of consulting and quantum security. SMEs and startups with limited resources, a shift to PQC could pose a resource crunch leading to competitive disadvantage. Indian startups are well-positioned to offer scalable and affordable quantum-secure solutions for Dutch SMEs, while Indian IT consulting firms can support the capacity building agile strategies.

Another strategic avenue for engagement could involve collaborative efforts to accelerate the development of practical sector-specific standards and guidelines for PQC migration—such as partnerships between institutions like De Nederlandsche Bank (DNB) and the Reserve Bank of India (RBI) in the banking and financial sector.

Quantum Key Distribution (QKD) represents another high-impact area for collaboration. Initiatives can include co-development of components for quantum networks such as quantum repeaters and memory modules, with the Netherlands contributing fabrication and photonics testing capabilities, and India offering system integration expertise, scalable manufacturing, and quantum talent. For example, Indian companies with expertise in optical components, such as QNu Labs, can collaborate with Dutch partners like Q*Bird or KPN to jointly develop low-cost QKD modules, combining Indian manufacturing strengths with Dutch systems design capabilities.

Pilot demonstrations of secure networks and proof-of-concept for hybrid PQC-QKD systems would provide global visibility and allow researchers across both nations to work on device and protocol interoperability. For instance, TNO (Netherlands), C-DAC and C-DOT (India) could co-develop an environment for supporting applications, testing interoperability, and developing regulations for quantum-safe communication.

India's DST and MeitY are actively supporting and investing in in photonic chips and communication research. These efforts present a timely opportunity for joint academic and startup-led projects between India and the Netherlands, aimed at building shared capacity and advancing technology readiness. **Strengthening enabling technologies** like photonics and cryogenics through such collaborations will serve as a key enabler across the broader quantum technology ecosystem.

Furthermore, India and the Netherlands can **jointly contribute to global standardization efforts** and **align engagement in international forums** such as Global Forum on Cyber Expertise (GFCE), International Telecommunication Union (ITU), United Nations efforts in quantum, and International Organization for Standardization (ISO), International Electrotechnical Commission (IEC), and IEEE.

At the policy level, both countries should establish an Indo-Dutch Quantum Security Dialogue that brings together policymakers, defense and telecom regulators, and national security experts. This dedicated track should address critical issues such as dual-use risks, secure information exchange, and intellectual property protection in defense contexts. In parallel, a joint working group on quantum information security—led by India's STQC (Standardization Testing and Quality Certification) Directorate and DSCI (Data Security Council of India), and the Netherlands' National Cyber Security Centre—can drive alignment on standards, benchmarking, and algorithm testing under real-world constraints. Telecommunications Standards Development Society India's (TSDSI) White Paper on Standardization Opportunities for Quantum Communication Technologies identifies tangible streams for collaboration and can be used to guide pilot studies. Existing platforms such as EU Project SESEI (Seconded European Standardization Expert in India) for standardization and regulatory alignment can be utilized to initiate these discussions. Regular coordination through these mechanisms will help shape shared norms on quantum cybersecurity and encryption at the international level.

Development of training programs and sector-specific awareness sessions to equip government and industry professionals with a practical understanding of quantum information security will foster informed adoption and strengthen institutional readiness across critical sectors.

2.2. Collaboration in Key Sectors

To translate quantum research into tangible economic outcomes, it is essential to foster partnerships across strategic sectors such as telecommunications, BFSI (banking, financial services, and insurance), manufacturing, aerospace, space technologies, and healthcare. A targeted, sector-specific approach will allow India and the Netherlands to co-develop use cases, align research with market demands, help attract investment, and drive commercialization. Strategic recommendations for high-impact sectors, with example projects, are as follows-

- **2.2.1. Telecommunications:** QST can unlock new revenue streams for telecom sector through quantum secure communications and next-generation network infrastructure. Joint collaboration initiatives, as mentioned in previous section, can focus on developing PQC and QKD systems and integrating quantum encryption protocols within telecom frameworks. For example, Dutch telco could partner with India's Bharat 5G and 6G alliance to demonstrate post-quantum-secured backhaul.

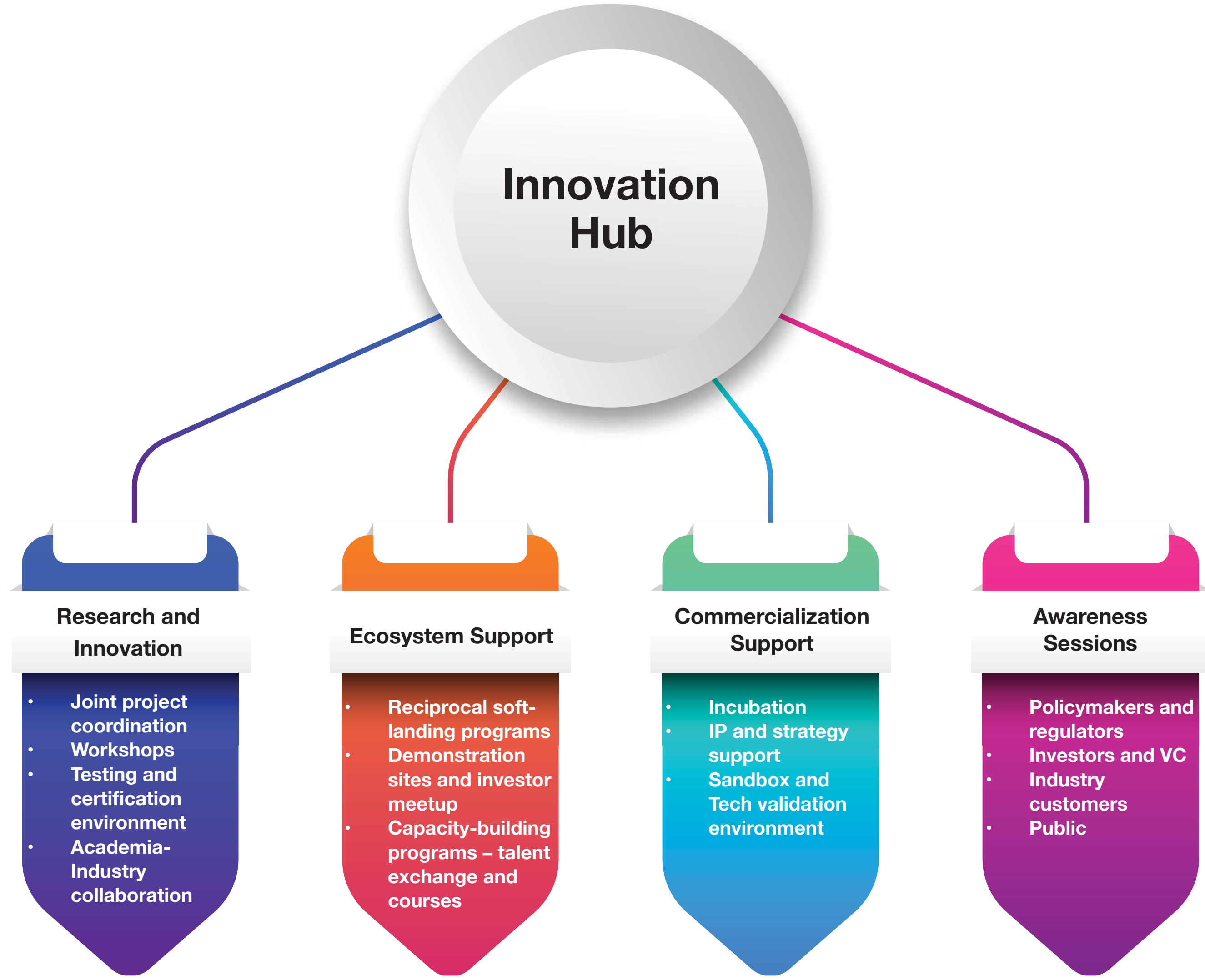
- **2.2.2. BFSI:** The BFSI sector stands to gain significant advantages from quantum technologies through enhanced fraud detection, sophisticated anti-money laundering (AML) mechanisms, and quantum secure cryptographic solutions. With countries' expanding financial institutions, and fintech ecosystem, Indo Dutch partnership creates a powerful synergy for financial technology innovation.

  The collaboration can be realized in the BFSI sector by working on key areas such as quantum-enhanced portfolio optimization and risk modeling, blockchain security, fraud detection, and credit scoring. Establishing joint regulatory sandbox for financial and insurance institutions to test quantum secure communications and quantum-computing applications in controlled environment, test interoperability with legacy infrastructure, develop standards and guidelines for protocols and cross-border transaction in quantum era.

- **2.2.3. Manufacturing:** Quantum sensing, simulation, and optimization tools offer transformative potential for manufacturing through predictive maintenance, system optimization, material design, and process enhancement. By utilizing QST, components performance and production can be enhanced, enabling lighter, faster, and more energy-efficient products, for example use of quantum gyroscope in robotics and precision manufacturing. A partnership between the two nations can accelerate the commercialization of advanced materials and technologies for industrial applications, including high-precision quality control in manufacturing.

  India's large-scale manufacturing base—particularly in electronics, automobiles, and machinery—positions it as a key player in scaling the production and industry applications of QST. The

Fig 25: Innovation Hub



Netherlands offers complementary strengths through its global leadership in materials science and advanced manufacturing, particularly in semiconductors, photonic devices, and cryogenics.

India and the Netherlands should explore targeted manufacturing partnerships to deliver strategic and economic value while fostering a resilient and integrated quantum supply chain. Joint initiatives could focus on co-developing critical quantum hardware, optical components, and control systems, as well as building specialized fabrication infrastructure for quantum applications. For instance, Dimira Technologies (India), Quanastra (India), and QuantaMap (Netherlands) contribute critical components to the quantum supply chain—cryogenic cabling, superconducting detectors, and defect inspection for quantum hardware, respectively. Capacity-building for specialized components for quantum systems cancreate economic and strategic opportunity for both countries.

- **2.2.4. Aerospace Technologies:** The strategic alignment between India's rapidly growing aerospace sector and the Netherlands' strengths in QST presents a unique opportunity to pioneer quantum applications in aerospace, while creating substantial commercial opportunities. The Indo-Dutch track record in aerospace capacity building provides a strong foundation for advancing shared objectives and catalyzing innovation in QST. Notably, existing partnerships—such as those between the Netherlands Space Office (NSO) and the Indian Space Research Organization (ISRO), and between TU Delft and the Indian Institute of Space Science and Technology (IIST)—have established robust channels for space technology transfer and collaboration.

A key opportunity lies in the joint development of satellite-based QKD systems, which can offer robust communication security for civilian applications. Additionally, quantum-enhanced navigation systems present a high-value area for collaboration, with the potential to transform precision positioning and timing capabilities. Beyond these, bilateral efforts can also focus on addressing critical global challenges by co-developing advanced quantum sensors for earth observation, atmospheric monitoring, and climate modelling. Interdisciplinary projects which fall under existing Indo-Dutch collaboration and funding levers, such as quantum gravimetry payloads to improve mineral and water resource mapping via satellite, can be explored as pilot studies.

To support these ambitions, shared facilities for exchange programs and testing of space-grade quantum payloads will be essential, accelerating the innovation cycle and ensuring the resilience of technologies in the harsh conditions of space deployment.

- **2.2.5. Biotechnology, Pharmaceutical, and Healthcare:** QST offer transformative potential across diagnostics, imaging, and biomedical research, presenting a compelling opportunity for collaboration between India and the Netherlands. India's expansive healthcare market and clinical research infrastructure, paired with the Netherlands' leadership in medical innovation, provide an ideal foundation for the joint development, validation, and commercialization of quantum sensing and computing solutions. Institutions such as AIIMS, Leiden University, and Erasmus MC could collaborate on advanced NV-based diagnostics and quantum-enhanced MRI, NMR, and MEG technologies, with pilot programs to integrate and test these tools in real-world clinical settings.

Further collaboration could focus on quantum computing applications in drug discovery and genomics such as molecular simulation, protein-folding analysis, and sequence alignment—through joint programs co-funded by India's Biotechnology Industry Research Assistance Council and the Netherlands' Health~Holland. To support these efforts, both countries should work toward streamlining regulatory approvals, facilitating cross-border movement of quantum sensing components, and harmonizing clinical trial processes.

Sector-specific initiatives help create defined pathways for commercialization, attract investor interest, and encourage public-private collaboration—building a strong, application-oriented quantum ecosystem in both countries. To further support sustainable ecosystem development, both countries should host sector-specific quantum awareness session hackathons with industry partners to solve real-world problems.

2.3. Dedicated Innovation Hub

To catalyze sustained collaboration of QST and accelerate technology transfer, India and the Netherlands should prioritize the establishment of bilateral quantum innovation hubs. These hubs would serve as **physical and virtual platforms** that bridge academia, industry, and government, enabling co-development, testing, and scaling of quantum solutions.

The innovation hubs should be centered at leading technical institutions, academic laboratories, and start-ups in both countries. This model can also serve to connect the Netherlands' Quantum Delta NL hubs with India's Quantum Thematic-Hub counterpart, creating an integrated bridge for cross-border collaboration.

Dedicated innovation hubs would serve multiple functions-

- Act as Centres of Excellence for quantum subdomains
- Support joint research, startup incubation, and policy coordination.
- Facilitate reciprocal soft-landing programs for industry.
- Host capacity-building programs, workshops, and investor roundtables.
- Organize awareness programs for policymakers, regulators, and industry leaders.
- Establish demonstration sites to showcase real-world quantum applications, increasing visibility to nvestors, customers, and regulators.
- Offer quantum testbeds and sandbox to validate technologies prior to commercialization.
- Offer startups and research teams legal and technical expertise to navigate joint IP ownership, patents, licensing, and commercialization strategies. This would provide local ecosystem with tools to scale and protect innovations across borders.

A key objective of the proposed innovation hubs is to establish a clear roadmap for engaging private industry, especially in device development and commercialization. Recognizing the capital-intensive demands for quantum infrastructure, **public–private partnership (PPP)** models should be actively promoted for co-financing the establishment of hubs, certification laboratories, and technology accelerators. This collaborative framework would bring together local and international universities, corporations, venture funds, and certification bodies to drive innovation and commercialization.

The dedicated hubs can provide structured workforce mobility and talent development programs. The hubs should serve as training grounds for quantum professionals, hosting short-term and long-term exchange programs, industry immersion sessions, and technical certification courses.

India and the Netherlands can **strategically utilize existing infrastructure** to support innovation hubs. For instance, quantum testbeds such as the Eindhoven quantum testbed can be linked with India's QKD research facilities at ISRO's Space Applications Centre (SAC), C-DOT, and the Raman Research Institute (RRI). Such interconnection would enable remote experimentation, interoperability trials, and the joint development of secure communication protocols. Additionally, cross-access to cloud-based platforms—such as the Netherlands' Quantum Inspire and India's emerging quantum processor prototypes—would broaden opportunities for collaborative research and validation.

Existing innovation hub, such as I-HUB Quantum Technology Foundation at IISERR Pune and TCS's Pace Port Amsterdam, can serve as a pilot site for this kind of engagement, providing Indian startups with a landing pad in Europe for product showcasing, market access, and customer engagement. Similarly, an affiliated facility in India could host Dutch startups and researchers, offering access to India's growing innovation networks.
By investing in well-designed innovation hubs, India and the Netherlands can institutionalize collaboration, reduce fragmentation, and build resilient infrastructure for long-term quantum technology leadership.

2.4. Testing and Certification

The commercialization of quantum technologies requires robust testing and certification frameworks to validate performance, security, and interoperability. India brings exceptional software validation capabilities and a rich talent pool, while the Netherlands contributes advanced hardware validation expertise and European regulatory experience. India has made significant strides in quantum sensing, materials research, standardization, and device-level applications, complementing the Netherlands' sophisticated testing methodologies and certification experience. Together, both nations can address the global challenge of reducing testing costs while accelerating qualification processes for quantum technologies.

A key commercialization opportunity lies in the development of a bilateral certification ecosystem, particularly for quantum technologies. Establishing **bilateral certification, testing, and interoperability labs**—aligned with international standards and compliance mechanisms like Common Criteria (CC) and the Federal Information Processing Standards (FIPS)—would provide a neutral and trusted space for both Indian and Dutch companies to validate their products.

Potential areas to initiate such collaboration could focus on quantum computing (especially photonics, superconducting, and cold atom platforms), quantum sensing and metrology (quantum coherence, entanglement fidelity, and noise analysis), and quantum communication (standards and validation). Joint validation and benchmarking can help significantly reduce the cost and time-to-market for domestically developed quantum technologies. Additionally, these labs should be developed with a reciprocal access framework that allows researchers, startups, and corporate partners from both countries to conduct performance benchmarking and compliance testing under shared governance. This would ensure that testing outcomes are mutually recognized, reducing redundancy and accelerating deployment timelines.

Housing these facilities within innovation hubs would reduce infrastructure costs and optimize resource use, while also establishing centers of excellence that support both technical evaluation and capacity building, making them more competitive for the global market. India's announced Quantum Standardization and Testing Labs to develop benchmarks and validation facilities can also serve as a bridge to establish larger bilateral collaboration in testing and certification.

Joint **fellowships and technical training programs**, including online courses, would develop the human capital necessary for quantum testing, calibration, and compliance. Specific capacity-building programs for QKD, QRNG, and quantum sensors certification would strengthen the innovation pipeline from research to market.

Capacity-building in QST testing and certification could help streamline market entry across both jurisdictions, reduce compliance burdens, and offer third-party validation crucial for attracting international investors. By combining their complementary strengths in collaborative testing and certification infrastructure, India and the Netherlands can shape the future of quantum technology commercialization. The shared infrastructure and methodologies developed through this collaboration will ensure that innovations from both countries are trusted, secure, and market-ready—benefiting researchers, businesses, and citizens alike.

2.5. Inter-Governmental Coordination

While the promise of India–Netherlands collaboration in QST is substantial, the path forward is fraught with legal, regulatory, and administrative hurdles that continue to slow momentum. These challenges are especially pronounced in quantum, where the strategic value of technologies intersects with concerns around security, commercialization, and global competitiveness. These challenges span intellectual property protection, national security concerns, export controls, regulatory misalignments, and administrative bottlenecks that disproportionately affect startups and research institutions.

While innovation hubs and above-mentioned instruments will provide grassroots, bottom-up recommendations and capacity building, complementary top-down initiatives and government-to-government collaboration is essential to resolve systemic issues.

To address the challenges, a comprehensive approach organized into three strategic streams is recommended. To implement this, the two governments should establish an India–Netherlands Quantum Cooperation Task Force, supported by dedicated working groups or roundtables and regular consultations with academia and industry, under each stream. This mechanism would facilitate ongoing dialogue, track progress, and align stakeholders across government, academia, and industry. The three streams are described below-

2.5.1. Enabling Access to Research Infrastructure: Procurement, Customs, and Investment

Potential Stakeholders:

- From India – DST, MeitY (including C-DAC), Ministry of Commerce and Industry, Ministry of External Affairs (MEA), National Security Council Secretariat (NSCS), SETS , TEC, C-DOT, Representatives from T-Hubs
- From Netherlands – Ministry of Education, Culture and Science (OCW); RVO, Dutch Authority for Digital Infrastructure (RDI), Ministry of Foreign Affairs, NEN, AIVD, CWI, Representatives from Quantum Delta Hubs

Quantum technologies are classified as dual-use—applicable to both civilian and defense sectors—making them subject to heightened scrutiny and risk assessment by national security, foreign affairs, and trade authorities in both countries. Hardware components, in particular, raises concerns which complicates international collaboration. Both countries include quantum technologies under their strategic control frameworks due to implications for secure communications, military applications, and national security.

These regulatory frictions are compounded by a fragmented and fragile supply chain. Many quantum hardware suppliers are small, thinly capitalized firms, often concentrated in specific regions. For both India and the Netherlands — research-grade quantum hardware, sensors, and testing equipment are often delayed by cumbersome import and export procedures, inconsistent documentation requirements, and prolonged customs clearance processes. These delays are particularly burdensome for startups and academic institutions, which often lack the logistical capacity to manage compliance-heavy trade regimes. With a supply chain that is already fragmented and dependent on small, specialized providers, such inefficiencies can stall projects, decelerate technology transfer, and disincentivize cross-border collaboration. Regulatory misalignments within the EU further complicate Indian participation in wider European quantum initiatives.

To support joint research projects and commercial deployments, both governments should implement streamlined procedures for customs clearance, export licensing, and procurement for research-grade quantum and enabling systems. A dedicated **"quantum research corridor"**—a fast-track mechanism for quantum-specific hardware, software, and test equipment—could help de-risk projects for startups and research labs while accelerating timelines for collaborative R&D.

Simplifying and mutually recognizing licensing and certification processes, sharing best practices in IP protection, and jointly develop certification and testing standards will be key to enabling seamless India–Netherlands collaboration in QST. India's Quality Council of India or National Accreditation Board for Testing and Calibration Laboratories (NABL) could collaborate with Dutch counterparts such as Netherlands Enterprise Agency (RVO) and Royal Netherlands Standardization Institute (NEN) to acknowledge each other's test results, speeding up market entry for quantum devices in both countries.

Harmonizing regulations, especially for items under strategic trade controls, will support India's integration into European quantum initiatives and ease Dutch engagement with Indian ecosystems. As export controls extend beyond quantum computers, both countries should initiate dialogue to identify and evaluate components, raw materials, and technologies essential for QST research and distinguish between research-grade and dual-use technologies. Quantum Delta NL's expertise in capacity building through investment screening, knowledge security, and supply chain services, coupled with QETCI's Quantum Value Chain Framework, can provide foundational knowledge for this collaborative approach. Given the rapidly evolving nature of QST capabilities and regulations, such dialogue will help align their approaches to dual-use risk management and prevent unnecessary barriers to legitimate scientific collaboration.

Finding **mechanisms to reduce repair and maintenance costs** for quantum and enabling systems presents another significant opportunity. Collaboration in this area can reduce supply chain dependencies for both nations and decrease technology costs. By reducing uncertainty and long lead times, the technology development and transfer lifecycle becomes shorter, ultimately attracting more investment into both quantum ecosystems.

Strengthening strategic trade relationships, especially in quantum components, is vital for driving research and manufacturing collaborations. Vertical integration in critical supply chain areas will address current fragmentation challenges where quantum startups and suppliers often lack sufficient capitalization.

2.5.2. Regulatory, Standards, and Policy Alignment

Potential Stakeholders:

- From India – DST, MeitY (including CERT-In and C-DAC), TEC, C-DoT, SETS, DSCI, Bureau of Indian Standards (BIS), National Critical Information Infrastructure Protection Centre (NCIIPC), Representatives from T-Hubs
- From the Netherlands –NEN, RVO, RDI, TNO, National Cyber Security Centre (NCSC) and Dutch Data Protection Authority, Representatives from Quantum Delta Hubs

A strategic opportunity for Indo–Dutch collaboration in QST lies in establishing a joint dialogue for the alignment of regulatory frameworks, standardization efforts, and national policy strategies. As quantum technologies evolve rapidly, the accompanying governance mechanisms must remain adaptive, inclusive, and internationally coordinated. This mechanism would convene science attachés, trade diplomats, legal experts, and quantum policymakers from both nations to harmonize approaches across key regulatory domains.

Specific focus areas would include export control regimes, intellectual property (IP) management, data sovereignty, ethical frameworks, and quantum-related risk governance. By fostering sustained legal and policy discourse, this platform would not only reduce friction in bilateral collaboration but also increase readiness for engaging in multilateral quantum governance.

Given their cross-cutting perspective on national quantum strategies and ecosystem development, this bilateral group would be well-positioned to coordinate and **drive sector-specific initiatives**. These would include setting standards, aligning regulations, sharing best practices, and building capacity through joint training, expert exchanges, and workshops. Importantly, this mechanism could also serve to evaluate and track the evolving quantum strategies of both countries, identifying areas of convergence and synergy among ecosystem players.

In the context of global standardization, harmonizing certification frameworks represents another significant area for collaboration. India and the Netherlands, by jointly engaging with international standard-setting bodies such as the International Telecommunication Union (ITU), International Organization for Standardization (ISO/IEC), and the European Telecommunications Standards Institute (ETSI), can contribute to shaping the future of quantum technology standards. This joint representation would not only ensure that their domestic priorities are reflected in global standards but also enhance the global competitiveness of their respective ecosystems.

Moreover, collaboration in regulatory and policy alignment should be embedded within broader multilateral frameworks such as the EU–India Trade and Technology Council (TTC). A coordinated bilateral approach would enhance both countries' influence within such platforms and amplify the impact of their quantum cooperation globally.

To institutionalize and operationalize this vision, a Memorandum of Understanding (MoU) between India's Ministry of Electronics and Information Technology (MeitY) and Department of Science and Technology (DST), and the Netherlands' Ministry of Economic Affairs, is recommended. Such MoUs would facilitate structured ecosystem development, joint regulatory foresight exercises, and ongoing policy alignment mechanisms.

2.5.3. Enabling Capacity-building for Quantum Ecosystems

To unlock the full potential of bilateral cooperation in QST, India and the Netherlands must establish a structured, policy-led channel for sustained dialogue and collaborative capacity-building. Such a channel would serve as the foundation for talent mobility, **targeted funding,** regulatory alignment, launching **targeted awareness sessions,** and institutional connectivity across academia, research, and industry.

This bilateral dialogue can identify and formalize partnerships and **strengthen government-to-government** agreements through instruments like Memoranda of Understanding (MoUs). These instruments will facilitate the knowledge-exchange, while signalling long-term commitment to joint innovation. Specific provisions should be made for streamlining talent mobility—including short-term researcher exchanges, visiting faculty appointments, and startup co-locations—supported by coordinated visa, IP, and institutional approval processes.

Complementing these efforts, both governments should **co-design innovation programs** and co-funding mechanisms that prioritize use-case-driven research with real-world applications. Funding should be disbursed through competitive calls managed by agencies such as the Dutch Research Council (NWO) and relevant Indian bodies, focusing on clearly defined deliverables, timelines, and impact metrics Leveraging already-established bilateral funding platforms, as outlined in the "India–Netherlands Bilateral Relationship" chapter, can accelerate implementation.

Administrative barriers add another layer of complexity. In the absence of a standardized bilateral cooperation framework, each new project must contend with visa challenges, institutional approvals, and ad hoc coordination mechanisms. These burdens are particularly discouraging for smaller players without dedicated legal or diplomatic support. Capacity building must also address gaps in the infrastructure supporting international technology transfer. Dedicated consulting resources or liaison services should be developed to guide startups and academic institutions through complex legal, regulatory, and operational landscapes.

India's recent launch of the first edition of India's International Technology Engagement Strategy for Quantum (ITES-Q), in April 2025, marks a step toward easing these constraints, but implementation and bilateral alignment remain ongoing tasks.

As both India and the Netherlands invest in QST that may influence data privacy, surveillance systems, autonomous decision-making, or **responsible innovation**, the absence of a shared ethical framework becomes a barrier. Without mutual agreement on principles for responsible innovation—especially in defense-related or proprietary applications—partners may hesitate to share knowledge or resources, fearing misuse or reputational risk. The lack of structured dialogue on the ethical implications of QST leaves a gap that can slow momentum in even the most technically promising collaborations. A shared commitment to responsible innovation must be embedded in all collaborative frameworks. Establishing regular policy dialogues, such as a dedicated quantum track at the India–Netherlands Tech Summit, would provide a platform to discuss policy harmonization, ethical considerations, and regulatory foresight. Regular bilateral innovation and trade missions organized by respective and innovaembassies can further deepen understanding and build trust between stakeholders.

Finally, this bilateral channel should be designed with scalability in mind. By aligning with broader European mechanisms such as Eurostars, Eureka, and Horizon Europe, India and the Netherlands can anchor their cooperation within larger multilateral innovation frameworks, unlocking access to additional funding, expertise, and markets.

By proactively addressing administrative, diplomatic, and policy-level barriers—and embedding trust-building and legal harmonization mechanisms—India and the Netherlands can move from fragmented coordination to a forward-looking, high-impact quantum partnership. This approach will not only strengthen bilateral outcomes but also help shape a more connected and resilient global quantum ecosystem.

Report Conclusion

QST sit at the confluence of scientific ambition, geopolitical transformation, and societal need. QST demands an approach that is not only innovative, but also inclusive, ethical, and globally collaborative. In this context, the India–Netherlands partnership emerges as a vital bridge—linking diverse perspectives, complementary strengths, and a shared commitment to advancing technology for the common good.

This report has outlined a comprehensive roadmap for bilateral cooperation, spanning ecosystem awareness, education, research and innovation, regulatory alignment, and strategic investment. These pillars provide a practical foundation for a high-trust, impact-oriented quantum collaboration. But to truly unlock the promise of QST, the partnership must also embrace broader imperatives—those that transcend bilateralism and speak to the future of global technology governance.

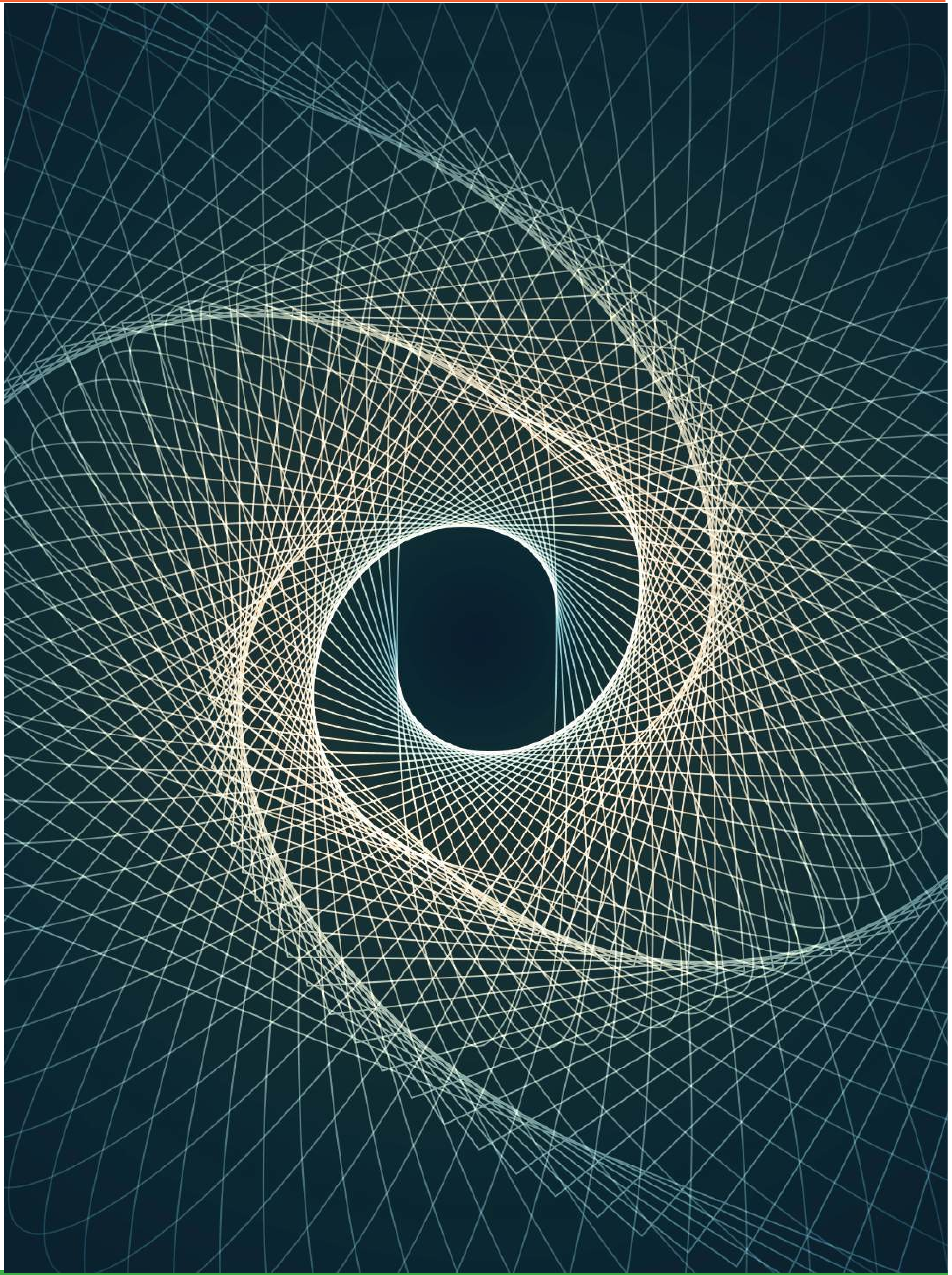
The convergence of advanced technologies—quantum, AI, semiconductors, cybersecurity—necessitates a diverse, multi-stakeholder approach. Governments, academia, industry, and civil society must co-create not only breakthrough innovations but also the frameworks to guide their responsible deployment. India and the Netherlands, by institutionalizing their quantum collaboration, can serve as a model for how open innovation, equity, and accessibility can be championed on the global stage.

Technology should be a bridge—not a barrier. It should foster cooperation, not division. In this spirit, quantum collaboration must be underpinned by shared principles: openness, transparency, freedom of inquiry, equitable competition, and strong intellectual property protections. These values will ensure that quantum progress remains rigorous, inclusive, and aligned with democratic ideals.

Realizing this vision also requires confronting structural challenges. The early-stage nature of the quantum market brings fiscal risk—particularly for startups and smaller players. Here, governments have a catalytic role to play, providing early funding, de-risking innovation, and enabling scalable, sustainable commercial pathways. Investment mechanisms must prioritize public value and long-term impact over short-term gains.

International partnerships, such as that between India and the Netherlands, are essential for combining expertise, creativity, and resources. They amplify national capabilities while accelerating the global diffusion of knowledge. Crucially, such partnerships must be rooted in good-faith cooperation—defined by mutual respect, ethical responsibility, and a commitment to collective benefit.

The path ahead is not without complexity. But if pursued with intent and integrity, the India–Netherlands collaboration can help define not just the future of quantum science, but also the norms that govern how technology serves humanity. In doing so, the two countries will contribute meaningfully to a trusted, equitable, and secure global quantum ecosystem—one that is built not by any single actor, but by a coalition of committed partners, working together to shape a better future.



1(a) Primary areas of interest/preferences within quantum technology:

- Quantum Computing
- Quantum Security
- Quantum Sensors
- Quantum Communication Networks
- Quantum Materials
- Quantum Simulation

(b) Are there any other areas of quantum technology that interest you? If so, please specify:

2(a) Are there any existing government grants, funding programs, or incentives to support joint quantum initiatives?

(b) In your opinion, what should be your country's main focus for collaboration with other countries in the field of quantum technology? (select 2)

- Joint research and development projects
- Industrial partnerships
- Innovation hubs in both countries
- Standardization and regulatory frameworks
- Trade Agreements
- Funding and investment in quantum startups
- Joint Conference alternating every 2 years in Netherlands and India in Quantum

3 Are you collaborating with other countries? Name them

4. Are you currently collaborating with any entity in the Netherlands/India if you are from India/ Netherlands? If so, please specify

A. Your Collaborator
B. Collaboration Details

5. Would you like to collaborate with an entity in the Netherlands? If yes, can you detail out the nature of collaboration you are looking for and if possible, name/s of entities that you wish to collaborate with?

6. In your opinion, what should the main priority for collaboration between India and Netherlands in the field of quantum technology? (multiple choice, multiple selects)

- Focus on quantum security (quantum cryptography and secure communication, or other areas)
- Quantum computing initiatives
- Development of quantum sensors for advanced applications
- Collaboration on quantum education and training programs
- Establishing joint innovation labs and technology transfer mechanisms
- Trade Agreements
- Any other? Please specify:

8 Survey Questions

7(a) What existing or future challenges do you perceive in the India - Netherlands collaboration on quantum science and technology?

(b) Are there any recommendations that you may have to address in these challenge areas?

8. How can India and the Netherlands leverage each other's strengths in quantum computing research?

9. What potential projects in quantum security could India and the Netherlands jointly undertake?

10. How can India and the Netherlands work together on Quantum Science and Technology to contribute to the Sustainable Development Goals (SDGs)?

11. What programs can be jointly implemented by India and the Netherlands do to promote diversity and inclusion within the Quantum Science and Technology sector?

12. How can the development of quantum sensors be accelerated through India-Netherlands collaboration?

13. What collaborative initiatives could be undertaken to enhance quantum communication capabilities for India and the Netherlands?

14. How can the two countries collaborate on developing and applying quantum materials for industrial use?

15. What regulatory frameworks or standards need to be harmonized facilitate seamless collaboration in quantum science and technology between India and the Netherlands?

16. What funding mechanisms or investment opportunities should be created to support joint initiatives?

17. Which end-user industries in India/Netherlands are most likely to benefit from advancements in quantum science and technology?

18. Which end-user industry in the Netherlands/India is your targeted segment for collaboration/selling?

19. In which fields within quantum science and technology do you see the most business opportunities for collaboration between the Netherlands and India?

20. Are there any future plans in the field of quantum science and technology that you want to highlight in the survey?

21. How can the development of quantum sensors be accelerated through India-Netherlands collaboration?

22. What joint initiatives could be implemented to enhance quantum communication networks between the two countries?

23. What funding mechanisms or investment opportunities should be

Additional Questions used during interviews

Supply Chain Development

- How can India and the Netherlands collaborate to develop a robust supply chain for quantum technology components and materials?
- What steps can be taken to ensure the availability and quality of critical raw materials and components?

Manufacturing Capabilities

- What advancements have been made in the manufacturing processes for quantum technology hardware in both countries?
- Are there any joint initiatives aimed at improving manufacturing efficiencies and reducing costs?
- Quantum Communication:
- How are telecommunications sectors in India and the Netherlands preparing for the integration of quantum communication technologies?
- What are the key challenges and solutions in upgrading existing IT infrastructure to support quantum technologies?

Data Security and Encryption:

- How can quantum technology enhance data security and encryption standards in both countries?
- What collaborative efforts are underway to develop and implement quantum-safe cryptographic solutions?
- Healthcare and Life Sciences
- What potential applications of quantum technology are being explored in the healthcare and life sciences sectors?
- How can collaborative research contribute to advancements in medical diagnostics, treatment, and drug discovery?

Financial Sector Integration:

- How can quantum technology be applied to improve financial services, such as secure transactions, fraud detection, and risk management?
- What collaborative projects are being undertaken to integrate quantum technology into the financial sectors of both countries?

Energy and Environment

- What are the potential applications of quantum technology in the energy sector, particularly in areas such as energy storage, optimization, and grid management?
- How are Indian and Dutch institutions collaborating to address environmental challenges using quantum technology?

Sustainable Practices

- How can quantum technology contribute to more sustainable industrial practices?
- Are there any joint initiatives aimed at leveraging quantum technology for environmental monitoring and conservation?

Cross-Sector Collaboration

- How are different sectors (e.g., telecommunications, healthcare, financial services) working together to leverage quantum technology?
- What frameworks are in place to facilitate cross-sector collaboration and knowledge sharing?

Impact on Value Chains

- How is the adoption of quantum technology expected to impact existing value chains in various sectors?
- What strategies are being implemented to manage this transition and ensure a smooth integration of quantum technologies?

Economic Benefits

- What are the anticipated economic benefits of integrating quantum technology into these allied sectors?
- How can both countries maximize the economic impact of their collaboration in these value chains?

References

Chapter 3: The Netherlands Quantum Ecosystem

Dutch Ministry of Economic Affairs and Climate Policy. (2019). *National agenda for quantum technology (NAQT). Government of the Netherlands.*

Dutch Research Council. (2021). *National growth fund allocation to quantum delta NL. NWO.*

IOplus. The Netherlands is excellent at quantum research but not at its commercial execution: 'Build a strong story around your product'. https://ioplus.nl/en/posts/the-netherlands-is-excellent-at-quantum-research-but-not-at-its-commercial-execution-build-a-strong-story-around-your-product

KWF Kankerbestrijding. Technology transfer.
https://www.kwf.nl/en/forresearchers/toolkitfordevelopment/technologytransfer

Netherlands Enterprise Agency. National technology strategy (NTS).
https://www.kia-st.nl/en/kia-key-enabling-technologies/national-technology-strategy-nts

PhotonDelta. (2023). PhotonDelta field lab overview. https://photondelta.com/

Quantum Delta NL. (2020). National quantum strategy implementation framework.

Quantum Delta NL. Quantum Delta NL expands strategy with renewed national growth fund support.
https://quantumdelta.nl/news/quantum-delta-nl-expands-strategy-with-renewed-national-growth-fund-support

QuSoft. (2023). Research highlights: Quantum software and cryptography. University of Amsterdam.
University Innovation NL. Home. https://universityinnovation.nl/

Welcome to NL. Quantum industry in the Netherlands.
https://www.welcome-to-nl.nl/quantum-industry-netherlands

Chapter 4: The Indian Quantum Ecosystem

Centre for Development of Advanced Computing. (2023). Quantum technology initiatives report. C-DAC.
https://www.cdac.in/index.aspx?id=quantum_computing

Department of Science and Technology. (2024). National quantum mission launch brief. Government of India.
https://dst.gov.in/national-quantum-mission-nqm

Indian Space Research Organisation. (2023). Annual report: Quantum communication R&D initiatives. ISRO.
https://www.isro.gov.in/AnnualReports.html

Ministry of Electronics and Information Technology. (2021). Quantum computing applications lab with AWS. Government of India. https://meity.gov.in

Office of the Principal Scientific Adviser. (2024). India's international technology engagement strategy for quantum. Government of India.

Society for Electronic Transactions and Security. (2024). Quantum security lab standards and guidelines. SETS.

Chapter 5: India-Netherlands Bilateral Relationship

NICCT. (2023, September 12). Launch NICCT India in the presence of Prime Minister Rutte.
https://nicct.nl/launch-nicct-india-in-the-presence-of-prime-minister-rutte/

Ministry of External Affairs, India. MOUs and agreements with the Netherlands.
https://mea.gov.in/rajya-sabha.htm?dtl/32159/QUESTION+NO190+MOUS+AND+AGREEMENTS+WITH+THE+NETHERLANDS

ThePrint. (2024, April 8). India & Netherlands to boost cooperation in water, agriculture & health sectors.
https://theprint.in/diplomacy/india-netherlands-to-boost-cooperation-in-water-agriculture-health-sectors/2068952/

Ministry of External Affairs, India. (2023, September 11). 12th India–Netherlands Foreign Office Consultations (FOC).
https://www.mea.gov.in/press-releases.htm?dtl/37793/12th_IndiaNetherlands_Foreign_Office_Consultations_FOC

Press Information Bureau, India. (2018, September 12). Cabinet apprised of MoU between India and Netherlands on cooperation in space technology. https://pib.gov.in/PressReleasePage.aspx?PRID=1496221

Centre for Cellular and Molecular Platforms (C-CAMP). (2023). WAH! Accelerator launched in collaboration with Netherlands Antibiotic Development Platform and AMR Global. https://www.ccamp.res.in/wah-accelerator-launched-collaboration-netherlands-antibiotic-development-platform-and-amr-global

TTC. 2023. Strategic Dialogue Report on Emerging Technologies. Brussels: EU–India Trade and Technology Council.
EUREKA Network. 2020. "GlobalStars Call India-Netherlands." https://eureka.global/globalstars.

Chapter 7: Recommendations

ISO/IEC JTC 1. 2024. Guidance for Emerging Quantum Technologies. Geneva: ISO/IEC Joint Technical Committee.

NABL. 2023. Testing and Calibration Standards for Quantum Devices. New Delhi: National Accreditation Board for Testing and Calibration Laboratories.

RVO. 2024. Netherlands Innovation Support for International Quantum Collaboration. The Hague: Netherlands Enterprise Agency.

European Commission. (2025). Quantum Technologies (RP2025). Interoperable Europe Portal. https://interoperable-europe.ec.europa.eu/collection/rolling-plan-ict-standardisation/quantum-technologies-rp2025

European Cluster Collaboration Platform. (2024). EU-India Matchmaking Event in Bengaluru 2024. European Commission. https://www.clustercollaboration.eu/content/eu-india-matchmaking-event-bengaluru-2024

ET Government. (2023, December 18). QETCI, MeitY launch Quantum Security Centre and release Quantum Value Chain report. https://government.economictimes.indiatimes.com/news/technology/qetci-meity-launch-quantum-security-centre-and-release-quantum-value-chain-report/106099153ETGovernment.com+2ETGovernment.com+2ETGovernment.com+2

Business Standard. (2023, April 1). RRI researchers, ISRO show secure satellite-based quantum communication. https://www.business-standard.com/india-news/rri-researchers-isro-show-secure-satellite-based-quantum-communication-123040100716_1.htm

NOTES

CONTACT US
info@qetci.org
NDE-IA@minbuza.nl