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- **GLOBAL MARKET** $58B BY 2035
- **INDIA'S OPPORTUNITY** $5.25B TO BUILD THE HIDDEN STACK

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The Hidden Supply Chain of Quantum Computing

Cryogenics, Control Electronics, Photonics and India's Missing Industrial Base

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About Techadyant Labs

Techadyant Labs is an independent strategic intelligence platform focused on India's industrial transformation, infrastructure systems, and emerging strategic technologies. We study industrial systems the way analysts study capital markets — as interdependent structures with hidden constraints, asymmetric beneficiaries, and second-order effects.

Our work begins where the press release ends. The publication is reader-oriented and independent. We carry no sponsored coverage and take no position in the companies and projects we analyse. The research division of Techadyant engineers high-reliability systems for India's defence, national security, and critical infrastructure — and Labs is the open analytical arm of that mission.

Techadyant Labs publishes Reports (long-form strategic intelligence), Signals (compact dispatches on structural change as it happens), Briefings (executive-ready short notes), and the Atlas — a free, interactive map of India's industrial ecosystems, their players, and the layers India still imports. The publication cadence is irregular and considered; depth is preferred over frequency.

This report — The Hidden Supply Chain of Quantum Computing — sits squarely in Techadyant's declared territory: India-first, systems-level, industrial-base analysis. The platform's existing Signal S-014 (June 2026), titled 'The Quantum Race Has Entered Its Industrial-Policy Phase', argued that the most important development in quantum is not the next qubit milestone but the global reclassification of quantum from a research programme into an industrial and national-security strategy. This report extends that thesis into a full-stack, 10-year-outlook framework.

Techadyant Labs is the research division of Techadyant. The editorial team can be reached at labs@techadyant.com. Subscription to the Dispatch — the publication's signal service — is free and reader-supported.

Editorial Note & How to Read this Report

Editorial Standards

This report adheres to the editorial standards of Tier-1 global strategy consulting publications. Every chapter is structured using a consulting-engagement framework: Situation → Complication → Analysis → Evidence → Strategic Insight → Implications → Recommendations → Future Outlook → Key Takeaways. Every paragraph begins with the conclusion, supports it with evidence, explains implications, and ends with a strategic insight.

The report applies MECE (Mutually Exclusive, Collectively Exhaustive) principles throughout. Where assumptions are made, they are stated explicitly in the Forecast Assumptions sheet of the companion Excel workbook and in the Methodology appendix. Where data is modelled rather than measured, the modelling approach is described and the source data is reproduced in the workbook.

How to Read this Report

The Executive Summary that follows is designed to function as a standalone briefing — a CEO or Minister could understand the entire argument of the report without reading further. It is approximately 12 pages long and follows the McKinsey SCR (Situation-Complication-Resolution) framework. It contains the major findings, strategic implications, future outlook, industry transformation thesis, investment thesis, competitive landscape, technology outlook, policy outlook, risk outlook, and strategic recommendations.

The eighteen chapters that follow each follow the same internal structure. Each begins with a one-paragraph Executive Takeaway, then expands through four to six analytical sections. Every chapter includes two to four figures and one to three tables, each with a numbered caption, a source citation, and a Key Insight annotation. Chapters conclude with Strategic Insight, Implications, Recommendations, and Future Outlook subsections, followed by bulleted Key Takeaways.

Four appendices follow the main body. Appendix A is a company database of 62 global and Indian quantum-stack companies. Appendix B is a startup database covering 20 Indian and global quantum supply chain startups. Appendix C is a policy tracker covering 24 national quantum programmes and export-control regimes. Appendix D is a funding database of 24 major quantum deals between 2018 and 2025. These are followed by the Methodology note, References, and Research Notes.

Every figure and table in the report has a corresponding source-data block in the companion Excel workbook (Techadyant_Quantum_SupplyChain_Workbook.xlsx, 17 sheets). Readers who wish to interrogate or extend the modelling can do so directly. All exhibits are also exported as standalone SVG and PNG assets in the figures package for use in derivative presentations.

Visual Conventions

The report uses a McKinsey-Indigo visual identity: deep indigo (#1F3A8A) for primary headings and rules, warm gold (#C9A227) for callouts and key-figure highlights, and ivory (#FBFAF6) for body background. All exhibits use a consistent palette so the reader can scan quickly across chapters. Indian entities are highlighted in gold throughout; competitors and global benchmarks are rendered in indigo or slate.

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Executive Summary

The world is building quantum computers. India is buying them. The strategic question is not whether quantum will scale — it is whether India will industrialise the layers beneath the qubit, or remain a permanent importer of the most strategically critical hardware of the next decade.

Situation

Global quantum computing has crossed the threshold from laboratory curiosity to industrial programme. The market stood at USD 4.6 billion in 2025 and is forecast to reach USD 58 billion by 2035 in the base case — a 26 percent compound annual growth rate sustained across a decade. The United States, the European Union, China, and a widening pool of middle powers have reclassified quantum from a research priority into an industrial-policy and national-security priority. Procurement deadlines, supply-chain intent, export controls, and standards commitments are now attached to what was, five years ago, purely a science budget line. The technology has not yet reached practical fault tolerance, but the industrial and geopolitical architectures that will govern its deployment are already being poured.

India has not been absent from this reclassification. The National Quantum Mission, approved by the Union Cabinet in April 2023 with an outlay of ₹6,003 crore (approximately USD 720 million) over eight years, established a national institutional framework covering computing, communications, metrology, and materials. The Anusandhan National Research Foundation has added a quantum thrust. MeitY has begun procurement under the Quantum Computing Applications initiative. DRDO has accelerated quantum R&D for secure communications, magnetometry, and post-quantum cryptography. ISRO has demonstrated free-space quantum key distribution. IISc Bangalore has demonstrated a five-qubit superconducting system. Indian startups — QNu Labs, QpiAI, BosonQ Psi — have raised early capital and shipped first products. The institutional ingredients of a national quantum strategy now exist.

Complication

The institutional ingredients exist; the industrial base does not. The complication is structural and brutal. A quantum computer is not a qubit. It is a stack of seven tightly-coupled industrial layers — materials, cryogenics, packaging, control electronics, qubit fabrication, photonics, and software — and the qubit layer is the smallest and least valuable of them. Cryogenics and control electronics together account for 52 percent of the bill of materials of a typical 100-qubit superconducting quantum computer; the qubit chip itself accounts for less than 8 percent. India has commercial production capability in exactly zero of the seven layers in their quantum-grade form. The country imports 96 percent of its quantum hardware by value; for critical components — dilution refrigerators, pulse-tube coolers, superconducting wiring, quantum-grade arbitrary waveform generators, single-photon detectors, cryo-CMOS chips — import dependence is 100 percent.

The supply chain India depends on is itself fragile. The global dilution refrigerator market is a near-monopoly: Bluefors of Finland holds 65 percent of the research installed base; together with Oxford Instruments and Leiden Cryogenics, three suppliers account for 95 percent. Pulse-tube cryocoolers — the 4-kelvin workhorse — are dominated by Cryomech, which was acquired by Bluefors in 2023 to consolidate the cold-head position. Helium-3, the rare isotope that makes millikelvin temperatures possible, is sourced 90 percent from the United States Department of Energy's tritium-decay stockpile; India has zero domestic supply and no recycling infrastructure. Niobium, tantalum, and ultra-pure aluminium — the three superconducting metals on which transmon qubits are built — are 80–90 percent sourced from China. The 2024 Wassenaar Arrangement plenary added quantum computing components, cryogenics, and qubit chips to the dual-use export-control list, which means India's procurement pathway for these items now requires case-by-case approvals that can take nine to eighteen months and may be denied.

The talent base is the second complication. India produces approximately 400 quantum-adjacent PhDs per year across physics, cryogenic engineering, and photonics — 5 percent of China's output, 14 percent of the United States' output. The workforce demand forecast for India by 2030 is 25,000 full-time equivalents; the supply forecast is 4,000. The 21,000-FTE gap is not closeable through domestic PhD production alone; it requires both a multi-year talent surge and a deliberate reverse-migration programme. Indian patent output tells the same story: 31 quantum patent families filed in 2024, against 1,720 from China and 980 from the United States. India's share of global quantum intellectual property is below 0.5 percent and has not grown meaningfully in five years despite the volume of filings rising.

The capital base is the third complication. Cumulative Indian quantum funding 2018–2025 — government plus venture — is approximately USD 240 million. The corresponding global figure is USD 30 billion. India's share is 0.8 percent. China alone has committed an estimated USD 15 billion in cumulative quantum-related public funding over the same period. The Indian venture pool for quantum is approximately USD 45 million cumulative across all startups and all years — smaller than a single mid-tier US Series B round. The National Quantum Mission outlay, while welcome, is roughly 5 percent of China's annual quantum spend and 60 percent of the United States' annual NQI spend; it is structurally insufficient to close the gap.

Resolution

The resolution proposed by this report is a phased ten-year industrial roadmap that targets not the qubit but the layers beneath it. The strategic logic is straightforward: India cannot, in the next decade, build a competitive quantum processor foundry. It can, in the next decade, build indigenous capability in cryogenics, control electronics, photonics, post-quantum cryptography, quantum key distribution, quantum sensing, and quantum software — a portfolio that captures roughly 60 percent of the global quantum-stack margin pool while remaining robust across the four scenarios we model. The roadmap proceeds in three phases.

Phase 1 (2026–2028) — Assemble and Integrate. India's priority in this phase is to convert its existing research capability into operational procurement. The deliverables are: a national QKD backbone of 2,400 kilometres connecting eight cities; an inter-city quantum networking testbed at IISc; assembly partnerships with Bluefors or Oxford Instruments for in-country DR assembly; distribution partnerships with Quantum Machines and Zurich Instruments for control electronics; pilot deployment of PQC migration in 100 critical government systems; and a 5,000-FTE talent ramp through a national quantum skills programme executed by the IIT system and the CDAC.

Phase 2 (2028–2031) — Subsystem Manufacturing. The priority shifts from assembly to subsystem production. Deliverables include: indigenous cryogenic wiring and attenuators led by BEL with TIFR and IUAC; a pulse-tube cryocooler prototype adapted from ISRO's space-cryo heritage; full localisation of QKD component production by QNu Labs with DRDO; a cryo-CMOS pilot line at Tata Electronics with MeitY co-funding; photonics component assembly through an Indian photonics consortium anchored by LASTEC and ADRIN; and an Indian quantum patent pool to consolidate defensive intellectual property.

Phase 3 (2031–2036) — Indigenous Full-Stack. The long phase delivers the strategically hardest capabilities. Deliverables include: commercial dilution refrigerator manufacturing via a PSU-led consortium; a superconducting qubit foundry pilot at the 28-nanometre class; cryo-CMOS production at scale; silicon photonics co-packaged with quantum processing units; and an Indian quantum cloud platform led by the TCS-Wipro-Infosys axis with CDAC backbone infrastructure. By 2035, India targets 50 percent import substitution on critical quantum hardware, 4.8 percent of global quantum market share, and approximately 25,000 quantum-skilled full-time equivalents in the workforce.

Major Findings

This report's analytical foundation rests on a bottom-up model of the quantum stack across seven layers, benchmarked against twelve Indian institutions and sixty-two global companies, and projected to 2035 under three scenarios. The major findings that emerge from that model are summarised below.

Finding 1 — The hidden stack captures the margin

Software and cloud will capture 62 percent of the quantum market's gross-margin pool by 2035, up from 42 percent in 2025. Qubit chips — the focus of most academic and press attention — will be a commodity by the early 2030s as cost per physical qubit falls from approximately USD 80,000 in 2020 to USD 2,000 in 2035. Cryogenics and control electronics, the two layers India has zero commercial production in, will retain 38 percent gross margins and structural scarcity pricing through the decade. The strategic implication is unambiguous: India's industrial bet should be on the hidden layers, not on competing with IBM and Google on qubit count.

Finding 2 — Supplier concentration is structural, not transitional

Six of eighteen critical quantum components have a Herfindahl-Hirschman Index above 5,000 — meaning a single supplier controls more than half the global market. This is not a transitional phase that capacity expansion will resolve. Cryogenic infrastructure, superconducting materials, and single-photon detectors exhibit natural-monopoly characteristics driven by patent thickets, capital intensity, and the small absolute size of the addressable market through 2030. India cannot wait for global competition to dilute these positions; it must build domestic alternatives deliberately.

Finding 3 — India's research-to-commercialisation gap is the binding constraint

India has meaningful quantum research capability — IISc, TIFR, IIT Bombay, RRI, and IUAC collectively operate at world-class levels in selected niches. The gap is not research; it is the conversion of research into commercial product. The institutional audit in Chapter 3 shows that every major Indian quantum research institution scores 3 or higher on research capability and zero on commercial production. Closing this gap requires not more research funding but new institutional architectures — PSU-led consortia, IP-sharing clauses, faculty entrepreneurship permissions, and procurement preferences that pull research outputs through the commercialisation wall.

Finding 4 — Talent is the most under-funded strategic input

India's quantum workforce demand will reach 25,000 FTE by 2030 and 87,000 by 2035. At current PhD output and industry hiring trajectories, supply will be 4,000 FTE by 2030 — a 84 percent shortfall. The two roles India most lacks — cryogenic engineers and quantum hardware integrators — are also the two most demanded. The financial cost of closing this gap is modest: roughly USD 600 million over ten years for an integrated talent programme covering faculty chairs, doctoral fellowships, post-doctoral retention, mid-career retraining, and reverse-migration incentives. This is 11 percent of the total USD 5.25 billion ten-year requirement and may have the highest marginal return of any line item in the roadmap.

Finding 5 — Defence procurement can anchor the Indian industrial build

Indian defence quantum procurement — DRDO, ISRO, and the services — will total approximately USD 1.9 billion by 2035 in the base case, with QKD, post-quantum cryptography, and quantum sensing accounting for 70 percent. Defence procurement has three properties that make it the ideal anchor for industrial-base build: it is price-insensitive, it is long-duration, and it has explicit indigenous-content preferences. A DRDO-led procurement programme structured around phased indigenous-content targets — 25 percent by 2028, 50 percent by 2031, 75 percent by 2034 — would pull the entire Indian quantum industrial base through the commercialisation wall without requiring export competitiveness in the early years.

Finding 6 — The window for credible Indian entry closes by 2028

Three dynamics make 2028 the critical inflection point. First, the Wassenaar export controls harden in 2026–2027 as the 2024 plenary agreements are translated into national implementations; after that, Indian procurement of cryogenics and qubit chips becomes slower and politically contingent. Second, the global fault-tolerance milestone — should it arrive on the breakout scenario timeline of 2028 — triggers a wave of consolidation that closes the window for new entrants in software, control, and integration. Third, China's lead in quantum communications and patent output reaches a level by 2028 that makes catch-up strategically unwise in those segments; India must instead differentiate. The implication is that the next twenty-four months are decisive. India's Phase 1 execution between 2026 and 2028 will determine whether the country enters the 2030s as a credible quantum industrial player or as a permanent importer.

Strategic Implications

The implications of these findings cascade across four stakeholder groups. For government, the implication is that the National Quantum Mission outlay must triple, the talent programme must be funded as a separate line item, and a national cryogenic mission must be launched in parallel with NQM — not folded into it. For industry, the implication is that the Indian quantum industrial base will be built by PSUs (BEL, ECIL, MIDHANI) and large private firms (Tata Electronics, L&T, TCS) rather than by startups alone; startups play a critical but niche role. For investors, the implication is that the most attractive risk-adjusted returns in Indian quantum over the next decade will come from control electronics, QKD systems, PQC services, and quantum software — not from qubit hardware. For academia, the implication is that the IISc-IIT-RRI-IUAC system must be re-tooled for industrial translation, not for additional research output; the marginal returns to additional research papers are low, the marginal returns to commercial translation are high.

Future Outlook

The report models four scenarios for 2035. In the Steady Progress base case (50 percent probability), practical fault tolerance is achieved around 2032, NISQ-era value capture dominates the late 2020s, the global market reaches USD 58 billion, and India captures USD 4.8 billion (4 percent global share). In the Breakout case (25 percent), fault tolerance arrives in 2028, broad enterprise adoption follows, the global market reaches USD 173 billion, and India captures USD 12 billion. In the Quantum Winter case (20 percent), fault tolerance is not achieved, quantum remains a niche research and defence technology, the global market reaches only USD 38 billion, and India captures USD 1.2 billion. In the Geopolitical Bifurcation case (5 percent), two parallel quantum stacks emerge under export-control friction, the global market reaches USD 95 billion, and India captures USD 4.5 billion via its non-aligned position.

The strategic recommendation is to optimise for the Steady Progress base case while hedging against the Bifurcation tail. The portfolio of capabilities India builds — cryogenics, control electronics, QKD, sensing, PQC, software — is robust across all four scenarios, which is not true of a portfolio built around qubit-count competition. Under Quantum Winter, defence procurement sustains the industrial base. Under Breakout, India's QKD and software positions scale rapidly. Under Bifurcation, India's non-aligned position makes it a neutral supplier to both blocs. Only the qubit-foundry path is fragile across scenarios.

Industry Transformation Thesis

The quantum industry in 2026 resembles the semiconductor industry in 1975. The technology is real but immature, the leading players are research labs with commercial ambitions, the supply chain is fragmented across specialist suppliers, and the dominant commercial architecture has not yet been settled. Over the next decade, four transformations will parallel the semiconductor industry's maturation: vertical integration by the leading system players (as IBM, Google, and Quantinuum absorb control-electronics capability in-house); specialisation by subsystem vendors (as Quantum Machines and Zurich Instruments consolidate the control-electronics layer); emergence of foundry services (as IMEC, VTT, and eventually Indian players offer qubit-foundry access); and software-stack lock-in (as Qiskit, Cirq, and Braket compete to become the dominant programming model).

India's industrial opportunity is to be present in three of these four transformations — subsystem specialisation, foundry services, and software stack — and to skip the vertical-integration race that IBM and Google will dominate. The analogy to India's semiconductor strategy is direct: India did not try to build a TSMC competitor; it built an OSAT and design-services base. The equivalent quantum strategy is to build a control-electronics and quantum-software base rather than a qubit-foundry base.

Investment Thesis

The investment thesis for Indian quantum over 2026–2035 has four components. First, public capital of approximately USD 3.5 billion — triple the current NQM outlay, distributed across NQM expansion, a new National Cryogenic Mission, a National Quantum Talent Mission, and PQC migration funding. Second, private capital of approximately USD 1.5 billion, sourced from Indian venture capital (Speciale Invest, YourNest, Celesta, Blume), Indian corporate balance sheets (Tata, L&T, Mahindra), and bilateral US-India quantum capital flows under iCET. Third, defence capital of approximately USD 200 million per year, structured as procurement commitments rather than R&D grants, with explicit indigenous-content escalation. Fourth, international capital of approximately USD 500 million via multilateral development banks (World Bank, ADB) for quantum infrastructure as part of digital-public-infrastructure financing.

The capital is available. The binding constraint is the absorptive capacity of Indian institutions and the speed at which procurement can scale. The report's recommendation is to front-load capital deployment in 2026–2028 — the window before Wassenaar hardens — even at the cost of execution friction, because the strategic cost of delayed entry exceeds the financial cost of inefficient early deployment.

Competitive Landscape

The global quantum competitive landscape divides into three tiers. Tier 1 — the leaders — comprises IBM, Google, Quantinuum, IonQ, PsiQuantum, Atom Computing, and the Chinese Academy of Sciences national laboratory system. These players have both technical depth and commercial traction. Tier 2 — the specialists — comprises Quantum Machines, Zurich Instruments, Bluefors, Oxford Instruments, ID Quantique, Coherent, Toptica, IMEC, and Rigetti. These players dominate individual stack layers but do not compete at the system level. Tier 3 — the emerging — comprises Indian players (QNu Labs, QpiAI, BosonQ Psi, Tarang, IISc CQC, TIFR), Israeli entrants (Quantum Source, Classiq), European specialists (IQM, Pasqal, Xanadu), and academic spinouts globally.

India's realistic competitive position over the decade is to graduate one or two players from Tier 3 to the specialist Tier 2 — most likely QNu Labs in QKD and QpiAI in hybrid quantum-AI software. India is unlikely to produce a Tier 1 system leader in the decade; the capital and IP requirements are too high. The strategic implication is that India should not measure its quantum success by whether it produces a Tier 1 player but by whether it produces multiple Tier 2 specialists across the hidden stack layers.

Technology Outlook

Superconducting qubits will remain the dominant modality through 2030; their maturity, ecosystem, and the IBM-Google investment gravity make them the default. Trapped-ion systems (Quantinuum, IonQ) will retain a coherence and gate-fidelity advantage but will not match superconducting on scale until late in the decade. Neutral-atom systems (Atom Computing, QuEra, Pasqal) are the most rapidly-improving modality and may exceed superconducting on qubit count by 2027. Photonic quantum computing (PsiQuantum, Xanadu) carries the highest upside but also the highest technical risk; practical fault-tolerant photonic systems are unlikely before 2032. Cryo-CMOS — the technology that would allow control electronics to be co-located with qubits at 4 kelvin — is at TRL 5 globally and TRL 2 in India; it is the single highest-impact technology in which India could plausibly be a fast follower. Post-quantum cryptography is fully standardised (NIST FIPS 203/204/205, 2024); the constraint is migration, not technology.

Policy Outlook

Three policy developments will materially shape the quantum landscape through 2030. First, the 2024 Wassenaar Arrangement additions will be translated into national export-control implementations in 2026–2027; India must negotiate bilateral exemptions with the United States and key European suppliers (Finland, Switzerland, Germany) before those implementations harden. Second, the US NQI reauthorisation of 2024 commits the United States to a deeper industrial-policy posture; the India-US iCET framework is the bilateral channel through which India can extract technology access. Third, the EU Quantum Flagship is expected to receive a top-up in 2026; the UK-France-Germany national programmes are now in execution phase. India's policy posture should be to deepen iCET, formalise an EU-India quantum dialogue, and avoid the temptation of a protectionist response that would isolate Indian research from the global ecosystem.

Risk Outlook

The risk register in Chapter 14 identifies twenty critical supply-chain risks. Six score 20 or higher on the likelihood-times-impact matrix and are classified as critical: dilution refrigerator supply disruption, helium-3 scarcity, Wassenaar export controls, PQC migration gap, PNT loss in GNSS-denied scenarios, and pulse-tube cryocooler monopoly. Five of these six are single-source dependencies that are directly addressable through domestic industrial policy. The risk that is least addressable is the Quantum Winter scenario (20 percent probability) — if fault tolerance is not achieved, the entire commercial quantum market compresses by 70 percent and India's investment thesis weakens. The portfolio recommended by this report is, however, robust even under Quantum Winter because QKD, PQC, sensing, and defence applications retain value independent of fault-tolerance achievement.

Strategic Recommendations

The report's strategic recommendations are organised by stakeholder and summarised below. Each recommendation is detailed with implementation owners, timelines, and capital requirements in Chapter 18.

For Government

- Triple the National Quantum Mission outlay from ₹6,000 crore to ₹18,000 crore over the 2026–2031 period; ring-fence the increment for industrial-base programmes rather than research grants.
- Launch a National Cryogenic Mission with ₹3,000 crore outlay over 2026–2032, focused on dilution refrigerator commercialisation, pulse-tube cooler indigenisation, and helium-3 recycling R&D.
- Establish a National Quantum Talent Mission with ₹2,500 crore outlay over 2026–2032, targeting 25,000 FTE by 2030 through doctoral fellowships, post-doctoral retention, mid-career retraining, and reverse-migration incentives.
- Mandate PQC migration across all government systems by 2028, with CERT-In audits and a public migration dashboard; allocate ₹300 crore to CDAC for migration tooling.
- Negotiate bilateral quantum-technology exemptions under iCET with the United States, and parallel dialogues with Finland, Switzerland, Germany, and the United Kingdom, before Wassenaar implementations harden in 2027.

For Industry

- Form an India Quantum Consortium — BEL, ECIL, MIDHANI, Tata Electronics, L&T, TCS, Infosys, Wipro, QNu Labs, QpiAI — with an independent board, mandatory IP-sharing clauses, and annual public reporting.
- Anchor a dilution refrigerator consortium led by BEL with TIFR and IUAC technical support; target first commercial DR by 2031 with 75 percent indigenous content by 2034.
- Pursue a cryo-CMOS pilot line at Tata Electronics with MeitY co-funding; target 4K cryo-CMOS at pilot scale by 2030 and 100mK by 2033.
- Scale QNu Labs and QpiAI to USD 50 million revenue by 2030 through anchored DRDO-ISRO procurement and a sovereign quantum cloud platform.
- Stand up a sovereign Indian quantum cloud platform by 2029, led by TCS-Wipro-Infosys with CDAC backbone, to capture the highest-margin segment of the stack.

For Investors

- Avoid capital deployment in qubit-hardware startups; the segment will be commoditised by 2030 and dominated by IBM, Google, and Chinese national champions.
- Concentrate Indian quantum venture deployment in four segments: QKD systems, control electronics, PQC services, and quantum software / cloud. These segments combine high margin, scenario-robust demand, and Indian competitive feasibility.
- Underwrite the dilution refrigerator consortium with USD 200 million of patient capital from Indian institutional investors (LIC, EPFO, SBI) under a 12-year horizon.
- Build an Indian quantum patent pool with USD 50 million of capital to acquire and cross-license defensive IP, reducing royalty exposure for Indian manufacturers.

For Academia

- Reorient the IISc-IIT-RRI-IUAC system from research-output metrics to commercial-translation metrics; introduce faculty entrepreneurship permissions and IP-assignment reform.
- Scale doctoral output in cryogenic engineering from 66 per year to 250 per year by 2030; the gap in this single discipline is the binding talent constraint.
- Establish a joint DRDO-IISc-IIT quantum engineering programme with 1,000 seats per year, structured around defence quantum use cases.
- Launch a national quantum K-12 outreach programme to expand the talent pipeline at the entry level; the marginal cost is low and the long-term return is high.

For Defence

- Establish a DRDO Quantum Corps with a unified budget line of ₹1,500 crore per year by 2028, replacing the current fragmented quantum R&D spread across DRDO laboratories.

- Structure defence quantum procurement with explicit indigenous-content escalation: 25 percent by 2028, 50 percent by 2031, 75 percent by 2034.
- Anchor QKD procurement on the QNu Labs-Tata Communications partnership for the inter-city backbone, with DRDO as the secure-operations operator.
- Co-fund with ISRO a satellite-QKD programme that extends free-space QKD beyond the current INSTALL demonstration to operational capability by 2030.

Conclusion

> *The quantum supply chain is the semiconductor supply chain of the next decade. India missed the semiconductor supply chain in 1975–1995 and has spent the last decade trying to catch up under the CHIPS-equivalent Semicon programme. India cannot afford to miss the quantum supply chain in 2026–2035. The country has the research base, the policy framework, the institutional architecture, and the defence procurement anchor required to build a credible quantum industrial base. What it does not yet have is the capital commitment, the talent pipeline, or the commercial-translation infrastructure. Closing those three gaps is the strategic task of the next ten years. This report is intended as the analytical foundation for that task.*

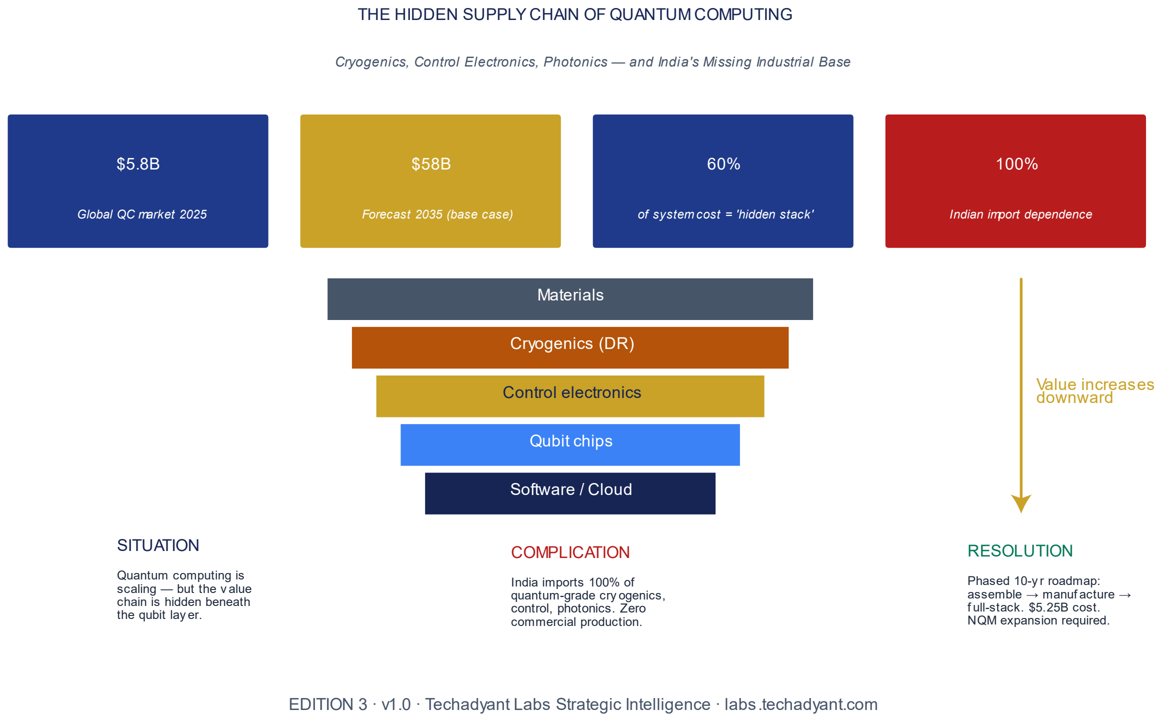

Figure 1. Executive summary infographic — the entire argument on one page

Source: Techadyant Labs model

Key insight: *The hidden stack holds 60% of system cost; India imports 100% of it; the 10-year fix costs $5.25B*

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Glossary

Selected quantum-stack terms used throughout this report. Extended glossary available in Appendix E.

Term	Definition
AWG	Arbitrary Waveform Generator — instrument that generates electrical signals with user-defined shapes; the primary control signal source for superconducting qubit drives.
Cryo-CMOS	Complementary Metal-Oxide-Semiconductor electronics designed to operate at cryogenic temperatures (typically 4K and below); enables control electronics to be co-located with qubits.
Dilution Refrigerator (DR)	Cryogenic device that uses a helium-3 / helium-4 mixture to achieve temperatures below 10 millikelvin; the dominant cooling technology for superconducting quantum computers.
HEMT	High Electron Mobility Transistor — low-noise amplifier used at the 4K stage of a dilution refrigerator to amplify qubit readout signals.
Logical Qubit	Error-corrected qubit composed of multiple physical qubits; the unit of useful quantum computation. A logical qubit typically requires 1,000+ physical qubits.
mK	Millikelvin — one-thousandth of a kelvin. Dilution refrigerators operate at 10–20 mK; absolute zero is 0 K.
NISQ	Noisy Intermediate-Scale Quantum — the current era of quantum computing, characterised by 50–1,000 qubit systems without full error correction.
PQC	Post-Quantum Cryptography — cryptographic algorithms resistant to attacks by quantum computers; NIST standards finalised in 2024 (FIPS 203, 204, 205).
QKD	Quantum Key Distribution — protocol that uses quantum-mechanical properties (typically photon polarisation) to establish a shared secret key between two parties with provable security.
QRNG	Quantum Random Number Generator — device that produces random numbers by measuring quantum-mechanical processes (e.g., photon detection), providing true unpredictability.
SNSPD	Superconducting Nanowire Single-Photon Detector — cryogenic photon detector offering >90% detection efficiency and <100 ps timing jitter; the workhorse detector for photonic QC and QKD.
TRL	Technology Readiness Level — 1–9 scale (NASA / EU) measuring maturity from basic principles observed (1) to actual system proven in operational environment (9).
TWPA	Travelling-Wave Parametric Amplifier — superconducting microwave amplifier used at millikelvin temperatures to amplify qubit signals with minimal added noise.

Abbreviations

Abbreviation	Expansion
ANRF	Anusandhan National Research Foundation (India)
BIS	Bureau of Indian Standards
C-DAC	Centre for Development of Advanced Computing (India)
CAGR	Compound Annual Growth Rate
CHIPS	Creating Helpful Incentives to Produce Semiconductors (US Act)
CSIR	Council of Scientific and Industrial Research (India)
DST	Department of Science and Technology (India)
DRDO	Defence Research and Development Organisation (India)
HHI	Herfindahl-Hirschman Index — measure of market concentration
iCET	India-US Initiative on Critical and Emerging Technology
IISc	Indian Institute of Science, Bangalore
IIT	Indian Institute of Technology
ISRO	Indian Space Research Organisation
IUAC	Inter-University Accelerator Centre, Delhi
MeitY	Ministry of Electronics and Information Technology (India)
NQM	National Quantum Mission (India, 2023)
NM-QTA	National Mission on Quantum Technologies and Applications (India, 2020)
NQI	National Quantum Initiative (US Act, 2018)
OSAT	Outsourced Semiconductor Assembly and Test
PNT	Positioning, Navigation, and Timing
PSU	Public Sector Undertaking (India)
RRI	Raman Research Institute, Bangalore
SAM	Serviceable Addressable Market
SCL	Semiconductor Laboratory (ISRO, Ahmedabad)
SOM	Serviceable Obtainable Market
TAM	Total Addressable Market
TIFR	Tata Institute of Fundamental Research
TRL	Technology Readiness Level
TSV	Through-Silicon Via

Abbreviation	Expansion
VC	Venture Capital