Quantum Made in Bharat: the Path Forward

Bharat's quantum ecosystem: claims, evidence, and national direction

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Quantum Made in Bharat

Vision • Sovereignty • National Scale

Dedication and Vision

This work is dedicated to the profound mathematical and physical insight demonstrated by **Satyendranath Bose**, teacher of my teacher Sanjoy Kumar Mitter, whose pioneering ideas in 1924 laid the foundation for quantum statistics and continue to inspire Bharat's scientific journey.
This work is also dedicated to the spiritual lineage of Kriya Yoga masters as presented at https://www.realinstitute.live. The masters embody timeless teachings that unify the local and the cosmic. They serve as bright lighthouses guiding Bharat's journey forward into infinity.

Vision

We envision a future where **ion-trap quantum computers** are not confined to elite laboratories, but are accessible in every Bharat village—whether it is the remotest settlement, the highest hamlet in the Himalayas, or a community on an island. This vision embodies technological sovereignty and inclusive quantum empowerment across the nation.

Executive brief: stakes and timing

Core shift: Quantum is entering a phase where national capability, not isolated excellence, drives economic and strategic outcomes.

Bharat's moment: Bharat has crossed from exploratory research to ecosystem formation; the question is "how to lead," not "whether to invest."

Objective: Define leadership, concentrate effort, and convert structural strengths into durable national advantage.

Executive brief: propositions and path

Five propositions: Coherent national program; advantage in algorithms/theory/integration; maturity in quantum communication; talent as asset; gaps are executional.

Strategic direction: Set national metrics, concentrate infrastructure, anchor in strategic demand, and build export identity.

Outcome: Shape critical parts of the global quantum landscape on Bharat's terms.

Five propositions: overview

Claim I: Coherent national quantum mission-mode program.

Claim II: Competitive edge in algorithms, theory, and systems integration.

Claim III: Quantum communication is technically mature and strategically aligned.

Claim IV: Talent base is large and renewable; absorption is the constraint.

Claim V: Gaps are infrastructural and executional, not conceptual.

Claim I: Coherent national program

Mission mode: Centralized, cross-domain coordination across computing, communication, sensing, materials.

Risk absorption: State capacity to sustain long development timelines and avoid fragmentation.

Precedents: Mirrors successful approaches in space, atomic energy, and telecom.

Claim I: National Quantum Mission features

Funding authority: Centralized funding across key quantum domains.

Strategic linkage: Explicit connection to defense, infrastructure, and sovereignty.

Institutional mesh: Coordination among leading universities, labs, and public-sector institutions.

Claim I: Strategic meaning

Capability stance: Bharat is prepared to treat quantum as long-term national capability, not speculative experiment.

Governance strength: Programmatic coherence reduces waste and accelerates translation.

Trajectory: Foundation for agenda-setting rather than reactive participation.

Claim II: Advantage in algorithms and integration

Community depth: Decades-long, internationally integrated quantum information theory base.

Adjacencies: Strength in mathematical physics, control theory, complexity theory.

Systems DNA: Proven large-scale software and systems engineering at national scale.

Claim II: Why this compounds

Hardware convergence: Performance approaches physical limits; differentiation shifts to software and control.

Algorithmic leverage: Error mitigation and architecture-aware design compound over time.

Bharat-fit: These are Bharat's strongest intellectual domains.

Claim II: Define leadership by usable performance

Reject vanity metrics: Qubit counts are imported and often misleading.

Adopt practical metrics: Usable performance under realistic noise, resource, and cost constraints.

Outcome: Leadership rooted in deliverables that matter for deployment.

Claim III: Quantum communication maturity

Demonstrations: Fiber QKD networks; free-space and satellite links; multi-agency integration.

Alignment: Telecom scale, indigenous satellite/launch, defense-grade secure communication needs.

Readiness: Closer to operational deployment than fault-tolerant computing.

Claim III: Strategic meaning

Standards leadership: Opportunity to define architectures for secure quantum communication.

Direct leverage: Early leadership translates to immediate national security and infrastructure benefits.

Export vector: Systems, verification, and integration as defensible export strengths.

Claim IV: Talent is an asset; absorption is the challenge

Supply: Strong annual cohorts in physics, math, engineering; rising quantum PhDs.

Software pool: Vast engineers adaptable to quantum toolchains.

Constraint: Absorption limited by infrastructure and pathways into deployment roles.

Claim IV: Convert talent into capability

Infrastructure access: Expand experimental facilities and shared testbeds.

Applied pathways: Build bridges from academia to mission-oriented engineering roles.

Hands-on training: Reduce dependence on foreign labs; cultivate domestic hardware practice.

Claim V: Executional and infrastructural gaps

Fabrication limits: Few domestic facilities for quantum-grade devices.

Stack gaps: Cryogenics, control, and test infrastructure insufficient.

Translation drag: Slow move from lab demos to field deployment.

Claim V: Strategic meaning

Known challenges: Capital-intensive but tractable; Bharat has overcome similar constraints before.

Binding constraint: Execution speed and infrastructure density, not lack of national capacity or vision.

Response: Concentrate, scale, and operationalize.

Strategic direction: From capability to agenda

National metrics: Benchmark what matters for Bharat's priorities.

Infrastructure concentration: Shared hubs and facilities with mandatory cross-access.

Strategic anchoring: Tie programs to security, space, and critical networks.

Export identity: Focus on communication systems, algorithms, and integration frameworks.

National metrics of quantum leadership

Usable advantage: Algorithmic performance under real noise and cost.

Network resilience: Coverage, reliability, and security for quantum communication.

FT designs: Fault-tolerant architectures tuned to indigenous hardware paths.

Concentrate national infrastructure

Engineering hubs: Few national centers with full-stack capability.

Shared facilities: Fabrication, cryogenics, integration, and test accessible across institutions.

No duplication: Mandatory cross-institutional access; efficiency over fragmentation.

Anchor quantum in strategic demand

Security: National defense and secure communications as demand drivers.

Space/time: Navigation, timing, and space infrastructure integration.

Civil networks: Critical infrastructure hardening and modernization.

Build an export-oriented quantum identity

Systems: Secure communication architectures and deployments.

IP: Algorithmic intellectual property with hardware-aware optimization.

Verification: Integration and validation frameworks as service exports.

Quantum hardware: elevate to national priority

Enabling substrate: Hardware underpins algorithms, protocols, sensing, and security.

Sovereignty: Without domestic hardware, theory and software remain externally gated.

Imperative: Treat hardware as core national infrastructure, not a niche topic.

Strategic cost of hardware dependence

Roadmap dependency: External hardware trajectories shape domestic research agendas.

Access constraints: Limits via pricing, policy, and availability.

Exposure: Sensitive algorithmic and cryptographic work subject to foreign jurisdictions.

Training ceiling: Scale training is impossible without domestic platforms.

Historical precedent and inversion

Prior arcs: Space launch, nuclear engineering, supercomputing—built from initial weakness to autonomy.

Quantum inflection: Similar opportunity: sustained investment converts disadvantage to leadership.

Lesson: Organize for hardware; invest in infrastructure and human capital.

Hardware as a talent multiplier

Skill formation: Cryogenics, device fabrication, control electronics, system integration.

Hands-on necessity: Real noise, failures, and constraints cannot be learned in the cloud.

Workforce completeness: Convert theoretical strength into full-stack capability.

Algorithmic leadership via co-design

Tight loop: Algorithm design $\leftrightarrow$ noise models $\leftrightarrow$ hardware constraints.

Domestic feedback: Evolve algorithms to exploit specific architectural features.

Outcome: Robust, implementable advances rather than abstract optimizations.

Manufacturing as strategic infrastructure

Priority domains: Quantum-grade materials, cryogenics, precision control, scalable characterization.

Dual-use gains: Strengthens semiconductors, photonics, precision manufacturing, defense electronics.

National substrate: Facilities akin to fabs, satellite integration, and fuel cycles.

Ten-year national objective

Goal: Multiple domestically operated, cutting-edge hardware platforms (superconducting, photonic, ion, etc.).

Autonomy: No default reliance on foreign cloud access or imports.

Collaboration posture: Engage internationally from strength, not dependence.

Execution priorities: organizing for scale

Centers: National hardware centers with end-to-end capability from fabrication to integration.

Training: Large-scale programs for hardware engineers and experimental physicists.

Co-design: Mandate projects linking algorithm groups with hardware teams.

Operations: Long-term funding for operations, not just capex.

From users to owners

Transition: Move from consuming foreign machines to building national capability.

Policy: Deliberate, sustained funding and institutional commitment required.

Result: Hardware as the key that unlocks scientific leadership, workforce development, and sovereignty.

Ion-trap computing: strategic suitability

Maturity: Long coherence, high-fidelity gates, reproducible control.

Accessibility: Vacuum, RF, optics, control software within reach of Bharat industry.

Scaling path: Systems engineering over exotic materials; constrained by control architecture.

Ion-trap ecosystem readiness

Scientific base: Atomic physics, laser cooling, spectroscopy, quantum control, error mitigation.

Species & sources: Yb^+, Ca^+, Sr^+, Ba^+; tractable sourcing and domestic ion sources.

Fabrication & vacuum: Surface traps via MEMS; UHV engineering already practiced domestically.

Control electronics, lasers, and costs

Electronics: RF drives, fast DAC/ADC, FPGA/DSP control—modular, open stacks reduce dependence.

Lasers: Targeted investment localizes quantum-grade lasers; photonic integration reduces complexity.

Costs: Single 100–200 qubit system: INR 15–22 crore; scale can reduce to INR 5–8 crore.

Scaling impact: systems as infrastructure

Economies of scale: Unit costs drop with hundreds to thousands of systems; electronics dominate at 10,000+.

Deployment fabric: Populate labs, university consortia, defense centers, and industrial R&D.

Capability density: Transform quantum from scarce resource to national substrate.

Limitations, mitigation, and the launchpad

Limitations: Control complexity, gate speed, laser maintenance, footprint, FT scale, manufacturing throughput.

Mitigations: Modular architectures, automation, depth optimization, integration, standardized modules, purpose-built facilities.

Launchpad: Imperfect access beats none—ion traps at scale build confidence, spillovers, and accelerate transition to future platforms.

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About the Author

Aman Chawla, SMIEEE, is a Bharat researcher and a founder of the Paramahamsa Hariharananda Research Enlightenment And Life Institute, where he aspires to be a monastic-cum-researcher. His active research work spans quantum computing, information theory, and computational neuroscience. With over 390 citations and an h-index of 9, his publications explore axon interactions, ephaptic coupling, and the mathematical foundations of consciousness, alongside pioneering studies on quantum algorithms and brain-inspired computation. He integrates resilient automation pipelines, SVG and LaTeX design, and editorial curation for scholarly publishing. Bridging rigorous theory with cultural authenticity, Aman advances reproducible science, hardware automation, and inclusive training, embodying sovereignty and innovation in Bharat's primordial scientific and cultural journey. Aman Chawla is building a table-top ion trap quantum computer. The REAL Institute is preparing for submissions to the 2027 Parliament of World Religions.