

JULY-SEPTEMBER 2025

VOL 9 (1)

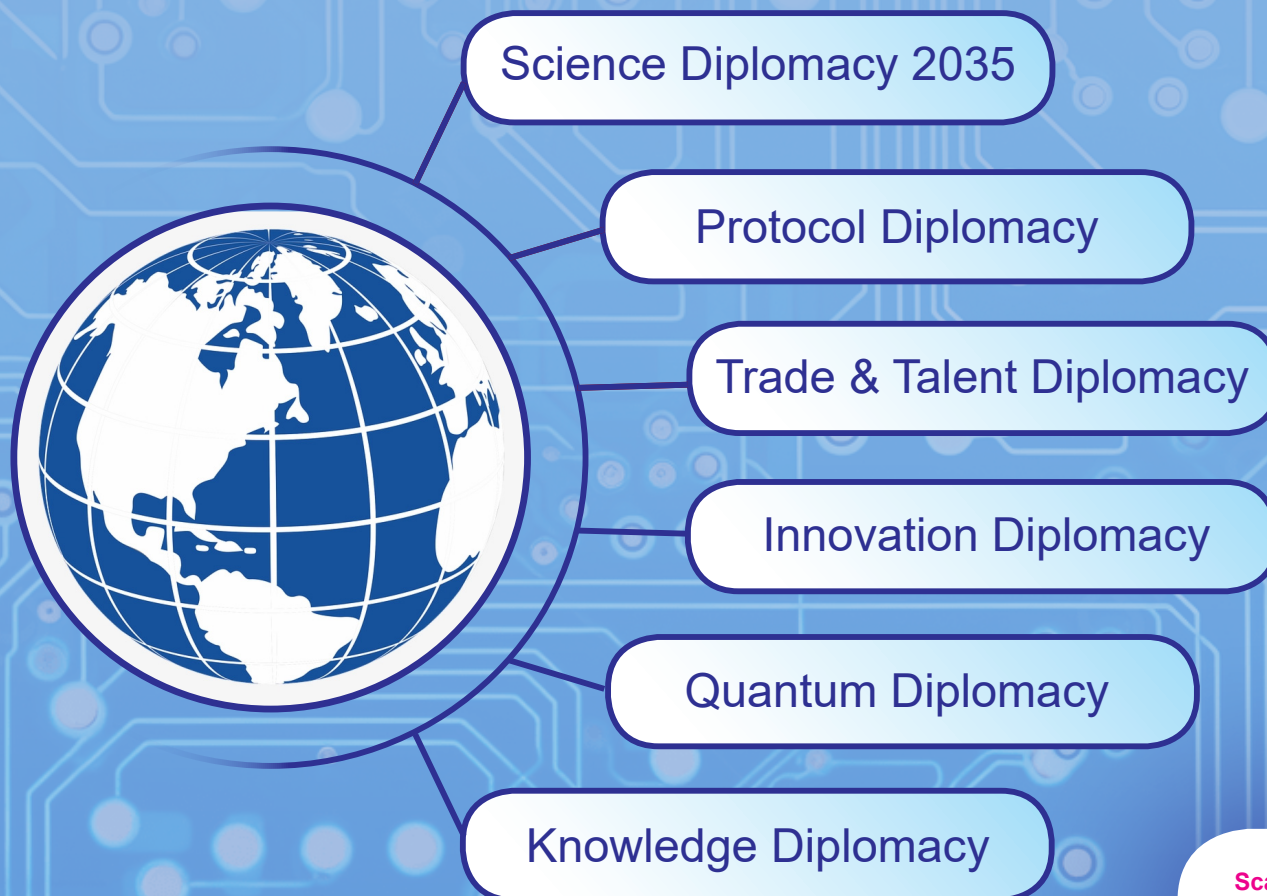
ISSN : 2456-5318

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Science Diplomacy

VOL 9(1) JULY-SEPTEMBER 2025

Director (*ex officio*)
CSIR-NIScPR

Editor
Dr Monika Jaggi

Design and Layout
Manender Singh

Published by

CSIR – National Institute of Science
Communication & Policy Research
(NIScPR)

Council of Scientific & Industrial
Research (CSIR)

Vigyan Sanchar Bhawan,
Dr K.S. Krishnan Marg,
New Delhi-110012, India



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Science Diplomacy in 2035: Action Regimes for a Changing Geopolitical Landscape

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Introduction

Over the past fifteen years, science diplomacy has moved from an idealised notion of universal collaboration to a more contested and strategically diverse arena. Geopolitical tensions, emerging technologies, and shifting alliances have challenged the belief that science could stand apart from politics. Instead, science diplomacy now encompasses a spectrum of practices shaped by national interests, cultural and political affinities, as well as crisis imperatives.

The concept of regimes of action provides a valuable lens for analysing these practices and anticipating their evolution. Each regime represents a relatively coherent configuration of actors and doctrines, but their boundaries are permeable, and hybrid forms often emerge. Looking towards 2035, understanding these regimes and their potential trajectories can help policymakers, diplomats, and research leaders to navigate an increasingly complex and fragmented global science landscape.

The Analytical Rationale for Regimes of Action

The regimes of action framework draws on political sociology and critical approaches to science diplomacy.^{1,2} Rather than classifying initiatives solely by function—as in the Royal Society/AAAS model¹ of science for diplomacy, diplomacy for science, and science in diplomacy—it examines the structural configurations that underpin international scientific engagement.

A regime of action combines three elements:

1. Actors: the institutions, states, and networks involved.
2. Doctrines: the principles and narratives guiding action.
3. Instruments: the policies, funding mechanisms, and infrastructures deployed.

This approach recognises that the same country may operate under different regimes in different contexts: engaging in open, multilateral science in one domain, while adopting a competitive, sovereignty-driven stance in another. For practitioners, the framework offers both descriptive and anticipatory value, helping to forecast regime shifts and adapt strategies accordingly.

The Four Regimes of Action

The Ideal Regime

The Ideal Regime rests on the vision of science as a global public good. It promotes inclusive governance, open access to data, equitable participation, and strong multilateral institutions. Examples include CERN, the Antarctic Treaty System, the International Space Station, and other large-scale collaborative research efforts in fundamental science.^{3,4} It thrives on mutual trust and reciprocity, but can be undermined by unequal distribution of benefits or geopolitical instability.

The Crisis Regime

The Crisis Regime emerges when urgent threats—pandemics, climate-related disasters, technological accidents—force rapid scientific cooperation. These efforts are often ad hoc and time-limited, mobilising flexible coalitions of states, agencies, and often research communities. The global COVID-19 response, the COVAX initiative, and the IPCC offer relevant examples.^{5,6} While capable of rapid mobilisation, this regime often struggles with short-termism, and trust deficits once the immediate threat subsides.

The Like-Minded Regime

The Like-Minded Regime is based on selective cooperation among actors with shared interests, potentially of different nature. It favours “club” formats, such as the G7 Science Ministers’ meetings or NATO’s DIANA programme.⁵ It can yield rapid progress on shared priorities, but tends to marginalise those outside the club and is poorly suited to addressing challenges requiring a truly global consensus.

The Sovereign Regime

In the Sovereign Regime, science is integrated into national strategies for power, influence, and economic competitiveness. This includes strategic autonomy in key technologies, control over knowledge flows, and competition for talent.^{7,8} National AI strategies, moonshot programmes with strict domestic control, and technology export controls all exemplify this regime. While it can accelerate innovation in priority areas, it risks duplication, reduced circulation of ideas, and even scientific isolation.

Strategic Dynamics and Interactions

These regimes rarely exist in pure form. Hybridisation is common: a country may support the Ideal Regime in basic research, the Crisis Regime for disaster response, the Like-Minded Regime for defence innovation, and the Sovereign Regime for sensitive dual-use technologies. The capacity to navigate across regimes depends on diplomatic skill, and the ability to manage tensions between openness and control.

The interplay between regimes is influenced by three main drivers: technological change, shifting geopolitical alignments, and evolving societal expectations about the role of science. For example, the rise of AI and quantum computing has blurred boundaries between civilian and military research, forcing governments to reconsider the balance between open collaboration and protective sovereignty.

Prospective Scenarios to 2035

The horizon year 2035 aligns with major strategic cycles in science and innovation policy, including the maturation of emerging technologies, climate mitigation targets, and global development agendas. It offers a meaningful vantage point for considering how regimes of action might evolve.

Scenario 1 – Resilient Multilateralism: The Ideal Regime regains prominence, with the EU, UNESCO, and others leading coalitions on climate, health, and sustainability. Open access and shared infrastructure are revitalised. The driving forces are mutual trust and strong institutions; the pitfalls are uneven benefit distribution and vulnerability to renewed fragmentation.

Scenario 2 – Bloc Politics Dominance: The Like-Minded Regime prevails, as geopolitical blocs consolidate their own research infrastructures and standards. Cooperation across blocs becomes rare. Forces at play include common security agendas and political values; pitfalls include exclusion of non-aligned actors and failure to address universal challenges.

Scenario 3 – Competitive Sovereignty: The Sovereign Regime becomes the norm. States enforce strict control over data and talent flows, engaging in open technology races. Driving forces are security imperatives and industrial competitiveness; pitfalls include costly duplication and reduced knowledge circulation.

Scenario 4 – Crisis Management Multilateralism: The Crisis Regime dominates, with coalitions mobilised in emergencies. While threats are managed effectively, long-term collaboration suffers. Forces are urgency and rapid mobilisation; pitfalls are weak institutional memory and trust deficits.

Regimes of Action in Science Diplomacy: 2035 Outlook

Regime of Action	Description	Possible 2035 Outlook	Main Forces at Play	Potential Pitfalls
Ideal	Science is treated as a shared global resource, anchored in universal values and inclusive governance.	Revitalised multilateralism with open access, fair participation, and robust common standards.	Mutual trust, open exchange, joint research infrastructures, and strong global institutions.	Loss of trust, unequal benefits, and disruption from geopolitical instability.
Crisis	Cooperation arises under pressure, often improvised, to respond to urgent global threats.	Flexible coalitions formed to manage pandemics, climate shocks, or technological breakdowns.	Urgency of crises, rapid-response capabilities, pooling of critical resources.	Short-term focus, weak follow-up, fatigue from repeated emergencies.
Like-Minded	Selective partnerships among countries sharing political alignment or cultural affinity.	Parallel systems within geopolitical blocs, with limited collaboration across divides.	Common security agendas, political alignment, and trusted “science clubs.”	Marginalisation of others, inability to address issues requiring global consensus.
Sovereign	Science embedded in national strategies for technological and geopolitical advantage.	Fragmented world of competitive sovereignty, with controlled knowledge flows and technology races.	National security, industrial priorities, competition for talent.	Duplication of effort, reduced circulation of ideas, and scientific isolation.

Implications for Practitioners

For those engaged in shaping or implementing science diplomacy, the regimes of action framework offers a practical way to read the strategic environment. Recognising which regime is in play, alone or in combination, can usefully inform choices (about partners, governance models, investment priorities, etc.).

Scenario thinking to 2035 is not about prediction but about preparedness. It enables institutions to test strategies against different plausible futures, identify early warning signals of regime shifts, in order

to design adaptable approaches. In all cases, maintaining channels for dialogue, even with competitors, remains essential for resilience.

Moreover, regime analysis encourages self-reflection. Policymakers and research leaders can ask not just what regime they are operating in, but what regime they want to foster in light of their long-term objectives and values. In a fragmented but interdependent world, strategic agility—the ability to move across regimes without losing credibility—is likely to be a decisive asset.

Conclusion

By 2035, science diplomacy will be shaped by the shifting interplay of Ideal, Crisis, Like-Minded, and Sovereign Regimes. Each offers different opportunities and risks, and none can be relied upon exclusively. The regimes of action framework, enriched with scenario-based foresight, equips practitioners to navigate this complexity. It underlines the need for trust-building, inclusive governance, and the careful balancing of cooperation and competition in pursuit of both national interests and global public goods.

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From Protocol to Partnership: India's Digital Public Infrastructure and the Rise of Protocol Diplomacy

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Introduction

In the early 2000s, India's international digital image revolved around software outsourcing, export of skilled talent, and IT services. But by the 2020s, the narrative had shifted. India is no longer merely exporting services, it is exporting protocols: modular, open-source digital architectures that deliver identity, payments, data exchange, and trust at a population scale.

This new form of diplomacy, rooted in Digital Public Infrastructure (DPI), represents a shift from economic service provision to norm-setting and institutional model-building. India's DPI model diverges from proprietary Western platforms or state-driven Chinese alternatives by offering technological sovereignty without dependence, especially to countries in the Global South.¹

India's approach amounts to a form of "digital non-alignment"—not choosing sides in the emerging tech Cold War but instead providing adaptable, rights-aware, and open architectures.² This is the essence of **protocol diplomacy**: diplomacy not through data dominance, but through institutional interoperability and trust-based infrastructures.

What is Protocol Diplomacy?

Protocol diplomacy reframes how states engage in digital cooperation by sharing governance logic and open infrastructure blueprints. DPI is not a plug-and-play SaaS (Software as a Service) product. Instead, it is a framework of modular public goods: identity systems, payment rails, and data-sharing protocols, designed for adaptability, transparency, and sovereign implementation.

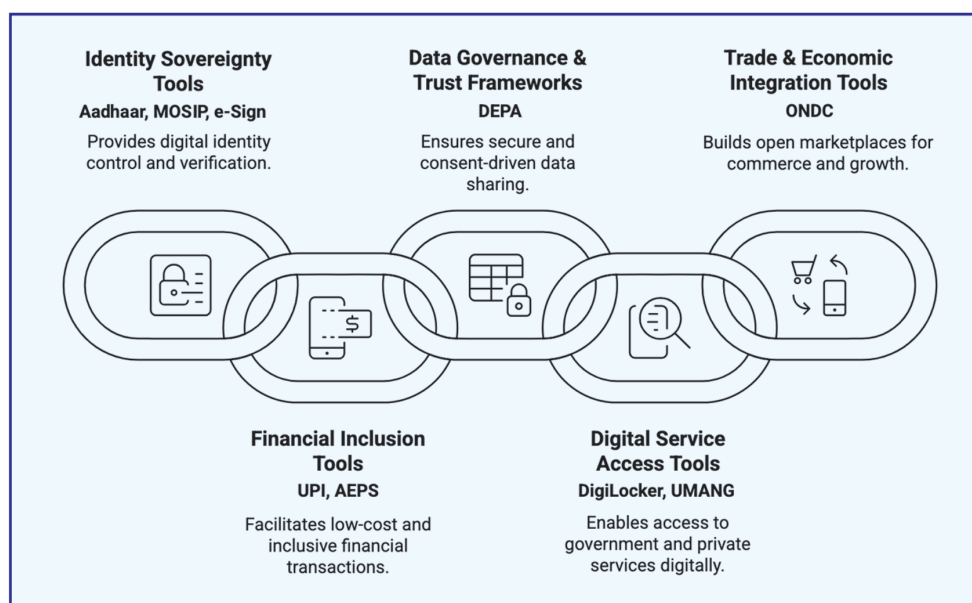
This model enables countries to govern digital architecture on their own terms. Instead of vendor lock-in, DPI offers reusable codebases, public Application Programming Interface (APIs), and open standards that can be locally owned and governed. It creates a "global digital commons" rooted in trust, not extraction.³ DPI is open by design, meaning that any nation can adopt, modify, and deploy components without compromising its legal or governance autonomy.⁴

Protocol diplomacy thus represents a soft power shift. It allows India and potentially others to lead not through control, but through a shared digital architecture that others can govern themselves.

India Stack: Scaling Trust at Billion Scale

India Stack is the most mature expression of DPI protocol diplomacy in practice. Unlike conceptual frameworks, the Stack is fully operational and scaled to over a billion users. It provides real-world evidence of how modular, interoperable systems can deliver public services at unprecedented scope. Its components include:

- [Aadhaar](#) (biometric ID),
- [UPI](#) (Unified Payments Interface: real-time digital payments),
- [DigiLocker](#) (cloud-based document verification),
- **DEPA** (Data Empowerment and Protection Architecture: data consent and sharing),
- [MOSIP](#) (Modular Open Source Identity Platform: open-source ID for export),
- [ONDC](#) (Open Network for Digital Commerce, a federated e-commerce network),
- **e-Sign** (Aadhaar-based electronic signature service),
- [AEPS](#) (Aadhaar Enabled Payment System: bank transactions using Aadhaar authentication),
- [UMANG](#) (Unified Mobile Application for New-age Governance: single mobile app for government services).



India Stack Framework (Source: Author).

Together, these tools form a layered digital foundation, allowing both public and private actors to deliver identity, payments, and data services securely and at low cost. For instance, as of mid-2024, Aadhaar covers 1.4+ billion individuals; UPI processes over 11 billion monthly transactions; DigiLocker hosts more than 6 billion documents.⁴

India Stack exemplifies how technological sovereignty can coexist with open innovation. It enables real-time delivery of welfare, access to banking, and public verification services, all without ceding infrastructure control to private monopolies.⁵

By separating infrastructure from application, India Stack empowers governments to govern, while letting markets innovate. This balance makes it globally relevant, especially to countries in the Global South seeking digital independence.

Diplomacy in Action: DPI in G20

India's Group of Twenty (G20) Presidency in 2023 brought DPI to the centre of international digital diplomacy. The G20 New Delhi Leaders' Declaration endorsed a voluntary, non-binding framework recognising DPI as an enabler of inclusive innovation and service delivery. In addition, India launched the Global Digital Public Infrastructure Repository – a collaborative platform providing open access to DPI standards, reference documents, and implementation case studies.⁶

Importantly, this diplomatic push extended beyond declarations. India hosted the G20 Digital Economy Ministers' Meeting, where 20 countries and 6 international organisations, including the Organisation for Economic Co-operation and Development (OECD), World Bank, United Nations Development Programme (UNDP), and United Nations Educational, Scientific and Cultural Organisation (UNESCO), endorsed the One Future Alliance (OFA) initiative. The alliance aims to support Global South nations by offering technical assistance, funding mechanisms, and knowledge-sharing to help them adopt DPI on their own terms. India also launched the India–UNDP DPI Repository as a cooperative tool to promote open-source adoption globally.

India's DPI diplomacy actively supports the achievement of Sustainable Development Goals (SDGs), facilitating low-cost and large-scale access to finance, healthcare, social protection, and digital identity.⁷ Countries, such as the Philippines, Ethiopia, Morocco, Sierra Leone, and Sri Lanka, have signed memorandums of understanding to implement DPI components like MOSIP, UPI, and DigiLocker. Kotschwar and Colter (2024) also note India's emerging digital partnerships with the African Continental Free Trade Area (AfCFTA) and bilateral engagements with the UAE and France, signaling the formation of a "trust coalition" around shared digital infrastructure.³

In this context, DPI is more than just a toolkit; it is a geostrategic offering. By exporting open digital architectures instead of proprietary platforms, India empowers other nations to shape their own digital futures. This shift reframes multilateral tech governance not as a battle for platform dominance, but as a shared effort to build sovereign, interoperable digital ecosystems.

Digital Sovereignty or Digital Dependency? Debating DPI Diplomacy

India's DPI diplomacy claims to empower digital sovereignty. However, a valid concern remains: Could it create dependency on Indian architectures by simply replacing one centre of influence with another?

Indeed, DPI systems, while open-source, embed certain assumptions: centralised identity (Aadhaar), biometric verification, and state-led design. These design choices may not fit countries with decentralised or privacy-focused legal traditions.⁵

However, the flexibility of implementation matters. DPI is not a product, but a reference architecture. Countries using MOSIP retain full control over data standards, storage, and governance. India's model is "government as rails, market as engine": the state builds neutral infrastructure, but the layers above are sovereign and contextual.¹

DPI reduces exposure to Big Tech's extraction logic providing countries with national control over core digital layers, while fostering private innovation atop them.⁷

The debate is not over whether DPI creates influence (any export of norms does) but whether it does so transparently, inclusively, and without lock-in. So far, protocol diplomacy has offered choice, not coercion – a meaningful distinction in a world fractured by digital asymmetries.

Over the coming decades, protocol diplomacy could reshape the geopolitical map of technology by redistributing influence from a small number of platform-owning powers to a broader coalition of nations co-developing open digital infrastructure. As more countries adopt modular DPI frameworks, global norms around data governance, privacy, and interoperability may shift toward multilateral consensus rather than unilateral standard-setting. This could weaken the dominance of proprietary ecosystems from

the United States and China, fostering a multipolar digital order in which technical standards emerge from collaborative governance bodies. At the same time, protocol diplomacy could create new spheres of influence around leading DPI exporters, meaning India's current leadership position may evolve into a long-term role as a convenor of digital governance alliances. Whether this results in equitable power-sharing or the emergence of new dependencies will depend on sustained inclusivity, transparency, and capacity-building within adopting countries.

Conclusion: Protocol Diplomacy and the Future of Multilateral Tech Governance

India's experiment with DPI has transformed a domestic governance innovation into a tool of international influence. Protocol diplomacy reframes the foundations of digital cooperation: moving away from proprietary control and toward shared stewardship of open, interoperable systems. In doing so, it shifts the source of soft power from dominance over platforms to the ability to convene, coordinate, and co-create standards.

This model matters because it challenges the binary choice between the corporate-led, extractive architectures of the West and the centralised, state-driven systems of the East. Instead, it offers a framework in which nations can retain sovereignty while benefiting from global interoperability – a form of digital multilateralism grounded in technical openness and political inclusivity. India's leadership here lies not only in the technical maturity of its DPI components, but in the diplomatic skill of translating them into globally relevant governance tools.

The rapid uptake of MOSIP, UPI, and DigiLocker in diverse political and economic contexts suggests that digital sovereignty does not require technological isolation. On the contrary, shared protocols can serve as a foundation for new "trust coalitions," where norms are negotiated collaboratively and infrastructure is co-owned by the states that use it. This opens the possibility of a multipolar digital order, in which power flows not from control over users' data, but from the capacity to enable secure, equitable, and adaptable participation in the global digital economy.

The opportunity is clear: governments, international organisations, and private innovators must work together to ensure that protocol diplomacy becomes a permanent pillar of global governance. This means investing in open, modular infrastructure; building capacity to adapt such systems to local needs; and creating governance forums where all stakeholders, not just early adopters, have an equal voice. The choice is stark: either accept a fragmented digital future defined by competing proprietary silos, or commit to a shared digital commons built on trust, openness, and cooperation.

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Tariffs and Talent: The Global Science Shake-up and India's Opportunity

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The deep entanglement of economics, science, and technology increasingly defines the twenty-first century. For much of the recent past, globalisation promised an unhindered flow of ideas, talent, and investment across borders, creating an interconnected research ecosystem. Yet the rise of tariff wars, particularly between the U.S. and its key trading partners, has exposed the fragility of that promise. While tariffs are often imposed as protective measures for domestic industries, their ripple effects extend far beyond commerce, seeping into the domains of scientific funding, international collaboration, and the circulation of knowledge. In the U.S., the convergence of geopolitical tensions and economic protectionism has coincided with reductions in funding for its premier science agencies, such as the National Science Foundation (NSF) and the National Institutes of Health (NIH). Coupled with shrinking allocations for education, these constraints have unsettled the global scientific community. Ongoing projects have faced abrupt suspension, graduate students and postdoctoral fellows find themselves confronting dwindling opportunities, and the long-standing perception of the U.S. as the undisputed hub of scientific talent is being challenged. At the same time, Europe and other regions are actively attempting to draw in researchers disillusioned by policy uncertainty in America, offering more stable funding and collaborative prospects. Within this shifting landscape, India is presented with a unique opportunity to not only stem the outflow of its own talent but to emerge as a global destination for cutting-edge science. The crucial question is whether India can create the right conditions to attract and retain international researchers, thereby reshaping its position in the evolving global knowledge order.

Tariff Wars and the U.S. Science Funding Crunch

At first glance, tariff wars appear to be confined to trade and economics, but their ripple effects extend far beyond import–export balances and market competitiveness. The chain of consequences reveals a direct link between tariffs and the health of science and technology ecosystems. Higher tariffs on imports drive up domestic prices, fuel inflationary pressures, and create fiscal imbalances for governments. In response, administrations often resort to budget realignments, channelling resources toward politically pressing or short-term economic needs while trimming allocations to areas that do not deliver immediate

returns. Unfortunately, research and education are often seen as expendable under such fiscal stress, making them vulnerable to cuts during financial turbulence.

In the U.S., two of the most critical pillars of science funding, NSF and NIH, stand at the centre of this storm. Together, these agencies support over \$80 billion annually in basic and applied science and engineering research, ranging from physics and computing to biomedicine and public health. Yet, amid tariff-induced fiscal pressures, reports already point to proposals in Washington DC, aimed at scaling back NSF's grants for basic sciences and reducing NIH's expansive biomedical research budgets substantially. The consequences of such decisions would be immediate and severe. University laboratories that depend heavily on federal research grants could face abrupt shutdowns. Carefully designed experiments may be abandoned mid-course, wasting years of accumulated data and painstakingly built research infrastructure. Recruitment freezes and stalled projects would leave graduate students stranded, especially those whose stipends and research continuity rely entirely on external funding.

Postdoctoral researchers, a backbone of American science who usually work under short-term contracts, would find themselves in even more precarious situations. With fewer grant renewals and shrinking institutional budgets, their positions could vanish overnight, creating a talent crisis in both academia and industry. Beyond the individual level, the broader innovation ecosystem would also suffer. Industry-academia collaborations, often catalysed by NSF and NIH support, would weaken, reducing the pace of technological development and commercialisation. Such a slowdown risks eroding the competitive edge of the U.S. in emerging areas like artificial intelligence, quantum technologies, biotechnology, renewable energy and other emerging and critical technologies.

The psychological toll on young researchers is another dimension of this funding crunch. PhD students, already navigating a demanding and uncertain career path, may lose morale as fellowships will dry up and pathways to stable academic or industrial jobs may become narrow. The allure of science as a long-term career weakens when students witness labs closing and mentors struggling for resources. Even the newly imposed fee on H-1B work visas adds to the prevailing uncertainty. All of this creates a pipeline problem, where fewer bright minds may choose to pursue scientific training in the future.

International collaborations also stand at risk. The U.S. has historically played a leading role in multinational research projects, from particle physics at CERN to global climate studies, vaccine development, and the Thirty Meter Telescope (TMT). With U.S. commitments shrinking, the collaborative balance could tilt, leaving gaps that other nations must scramble to fill. This is not merely an American crisis, but one that reverberates across the global scientific community. Laboratories abroad that depend on U.S. partnerships may find themselves underfunded or technologically isolated. The erosion of America's scientific presence thus threatens to destabilise the interconnected web of global knowledge production, slowing the pace of discovery at precisely the time when humanity faces complex, borderless challenges such as climate change, pandemics, and energy transitions.

In essence, tariff wars have unleashed an economic chain reaction that places science and technology in the crosshairs. What may begin as fiscal adjustments on trade policy ends up undermining the very foundation of innovation, jeopardising not only U.S. leadership in science, but also the vitality of the global research ecosystem.

Impact on Bilateral Scientific Cooperation

With massive cuts in NSF and NIH funding, bilateral scientific cooperation programs between India and the U.S. will suffer badly. During the Biden Administration, two countries made several arrangements for cooperation in emerging and critical technologies (iCET), like quantum technologies, communication, defence technologies, biotechnologies, space exploration, etc. Recently, ISRO and NASA launched a joint expedition, NISAR, but the implementation of future studies remains a question. Similarly, the Vaccine Action Program in India, supported by NIH, could be badly affected.

The European Magnet: Shifting Research Flows

For decades, the U.S. has been the undisputed global hub of science and technology, drawing talent from India, China, Latin America, and Europe. Nearly 40 per cent of postdoctoral researchers in the U.S. are foreign-born, a testament to its historically open research ecosystem and generous funding models. However, this dominance is now under strain. Visa restrictions, unpredictable immigration policies, and deep cuts in funding to institutions such as the NSF and NIH create an atmosphere of uncertainty. Ongoing projects may face abrupt stoppages, while PhD students and postdocs are increasingly anxious about their future career pathways.

In this shifting landscape, Europe has quickly positioned itself as the next magnet for displaced talent. The European Union's Horizon Europe Program, with its massive €95.5 billion budget for 2021–2027, is among the most ambitious research frameworks globally. Simultaneously, national research institutions such as Germany's Max Planck Society, France's CNRS, and the Netherlands Organisation for Scientific Research (NWO) offer structured fellowships and long-term postdoctoral opportunities. Even smaller countries like Switzerland and Denmark, with R&D spending between 3–4 per cent of GDP, are leveraging their strong science funding to absorb skilled researchers. As a result, graduate students who once dreamt of joining MIT or Stanford are increasingly applying to ETH Zurich, TU Munich, and other European institutes.

Yet Europe, despite its strengths, cannot accommodate the entire wave of displaced talent. Bureaucratic complexities, linguistic hurdles, and the resurgence of nationalist politics pose challenges. These limitations create a strategic opening for India to emerge as an alternative hub for global research talent.

India at the Crossroads: From Brain Drain to Brain Gain?

For decades, India has grappled with the challenge of “brain drain,” as its brightest minds often migrated to the U.S. and other advanced economies in search of better research facilities, greater funding opportunities, and more lucrative careers. Ironically, the present financial strain in the U.S. gives India an unexpected chance to reverse this historical trend. The key question now is whether India can bring back its own researchers and emerge as a global hub capable of attracting scientists from across the world.

India's scientific and technological landscape offers a combination of strengths and challenges. On the positive side, the country benefits from a vast and youthful population with strong capabilities in STEM disciplines. Over the past two decades, India has also built a robust and diversified R&D ecosystem, with achievements in areas such as space exploration through ISRO, pharmaceutical innovation, digital technology, and clean energy. Policy frameworks like the National Education Policy (NEP 2020) and the Science, Technology, and Innovation Policy (under consideration of the Government) demonstrate a long-term vision for integrating research, education, and innovation. Complementing these efforts are flagship programs such as Make in India, Startup India, and Digital India, which are fostering a vibrant entrepreneurial and innovation-driven environment. India recently announced a new fund of Rs 1 lakh crores for investment in R&D by the private sector in sunrise technology areas. This will allow researchers to be absorbed besides academic and scientific institutes. These initiatives highlight India's ambition to position itself as a global science and technology powerhouse.

Yet, the weaknesses are equally visible. India's R&D spending, at just 0.7% of GDP, lags far behind global leaders such as the U.S., China, and South Korea. Institutional bottlenecks, bureaucratic hurdles, and inflexible structures often slow progress and discourage young talent. Funding opportunities for postdoctoral researchers and early-career scientists remain limited, making it difficult to sustain momentum. Moreover, Indian universities and research institutions still lack the global visibility and branding that could make them truly competitive on the world stage.

To transform this scenario, India must see its challenges as avenues for reform. India can seize this moment by investing more aggressively in R&D, streamlining institutional processes, expanding opportunities for young researchers, and enhancing its universities' international reputation. If executed strategically, this shift could not only stem the outflow of talent but also draw global researchers to India, heralding a new era of "brain gain."

What India Needs to Do: Policy and Strategy Roadmap

In the wake of shifting global research dynamics, India has an opportunity to position itself as a new hub for displaced scientists and international talent. The first step in this direction would be the creation of a National Science Talent Mission (NSTAM) dedicated to attracting researchers worldwide who may face uncertainties due to shrinking budgets in the US and elsewhere. Much like the Marie Curie Fellowships in Europe, India could design competitive fellowship schemes that provide generous financial support, while also offering tenure-track opportunities in leading universities and research institutes, not only for Indians but for global researchers. To make this transition smoother, fast-track visas, relocation support, and family assistance must be embedded into the program, ensuring India becomes a viable alternative for global scientific careers.

Simultaneously, India can foster Global Research Clusters in key innovation cities such as Bengaluru, Hyderabad, Pune, and Delhi. These hubs should function with autonomous governance structures to minimise bureaucratic hurdles, while securing joint funding from both the government and the private sector. Equipped with cutting-edge laboratories, AI-driven computing resources, clean rooms, and collaborative infrastructure, these clusters can serve as magnets for international collaborations and multidisciplinary research.

Another vital strategy lies in expanding public–private partnerships (PPP) to reduce overdependence on government funding. India can build a sustainable and dynamic research ecosystem by encouraging leading IT firms, pharmaceutical companies, and energy conglomerates to co-invest in scientific innovation. For instance, large corporations such as Infosys or Reliance could drive AI and renewable energy advancements. At the same time, organisations like the Serum Institute might spearhead biomedical and vaccine research in collaboration with academic institutions.

A long-term solution also requires reforming higher education to make Indian universities globally attractive. Greater institutional autonomy for IITs, IISc, IISERs, AIIMS, and central universities will empower them to innovate in governance and academic design. Dual degree programs with global universities, flexible research fellowships, and competitive living stipends comparable to those in Europe or East Asia will help attract international students and postdoctoral researchers.

Finally, India must leverage its vast scientific diaspora and attract researchers worldwide. Many Indian-origin researchers in the US and Europe hold senior positions in labs and industries. Targeted programs encouraging their return through leadership roles, assured funding, and startup incubation support can convert the ongoing "brain drain" into a powerful "reverse brain gain," reinforcing India's global scientific standing.

Why Global Researchers Might Choose India

Although sceptics often point out that India continues to lag in certain aspects of research infrastructure, there are strong and increasingly persuasive reasons why global researchers might choose to work in India, provided that key policy gaps are addressed. One of the foremost advantages lies in the cost of living. Unlike the US or Europe, where research funds are quickly exhausted, India allows the same funding to be stretched significantly further, enabling researchers to support larger teams, conduct longer experiments, and pursue broader lines of inquiry without constant financial strain.

Equally important is the diversity and uniqueness of research problems available in India. The country's vast and varied landscape presents unparalleled opportunities for interdisciplinary study in areas such as public health, climate change, agriculture, and renewable energy. For example, India's demographic diversity and environmental challenges offer natural laboratories for developing solutions that can be scaled globally.

Adding to this is India's growing geopolitical stature. As a leader of the Global South and an active participant in international science diplomacy initiatives such as CERN, ITER, SKA, and, bilateral collaboration (with more than 80 countries) as well several multilateral collaborations, including G-20, BRICS, Indian Ocean Rim Association, Shanghai Cooperation Organisation, ASEAN, India offers an environment where research is not only about scientific advancement but also about shaping global policy and cooperation. With several steps taken to improve the Ease of Doing Research, India has significantly risen in the Global Innovation Index. India's cultural openness and long tradition of welcoming scholars from across civilisations provide a strong foundation for reframing its academic and scientific appeal in the 21st century, making it a fertile destination for global talent.

Risks and Challenges for India

India's ambition to attract global researchers must be tempered by an awareness of the challenges ahead. One of the biggest hurdles lies in bureaucratic complexity – grant approvals, fund disbursements, and institutional red tape often move at a frustratingly slow and opaque pace. Such delays can dissuade international scholars accustomed to faster, more efficient and transparent systems.

Another concern is the delicate balance between brain circulation and brain capture. While India may succeed in attracting researchers, many could view it as a temporary stop before moving on to resource-rich environments, leading to instability in long-term knowledge creation.

Equity also remains a pressing concern. If foreign researchers are offered significantly better funding, salaries, or privileges than domestic scientists, resentment could weaken morale within India's research communities. Simultaneously, persistent infrastructure gaps pose a structural barrier. High-end research demands cutting-edge laboratories, reliable power, and stable long-term funding in areas where India still performs unevenly. Without addressing these systemic shortcomings, even the most well-intentioned policies risk being cosmetic. To truly emerge as a global research hub, India must commit to deep, sustained, and structural reforms.

The Way Forward: India as a Science Diplomacy Leader

The path ahead for India lies in approaching global talent mobility not merely as a matter of absorbing researchers but as an opportunity to advance science diplomacy. By positioning itself as an inclusive and collaborative research hub, India can leverage this moment to strengthen its role in the international knowledge ecosystem. A key step in this direction would be the development of South–South research partnerships. Many African and Latin American scholars today face shrinking opportunities due to funding constraints in the U.S. and Europe. With its growing scientific infrastructure and cultural affinity with the Global South, India can offer an alternative platform for collaboration, training, and joint innovation.

Equally important is India's potential leadership in addressing global challenges that transcend national borders. From combating climate change and advancing renewable energy technologies to preparing for future pandemics, India has both the scientific expertise and moral credibility to drive collective action. By aligning its initiatives with the United Nations Sustainable Development Goals (SDGs), India can attract broader international support and funding while reinforcing its image as a responsible global actor. In an increasingly polarised geopolitical landscape, India has the unique opportunity to project itself as a neutral, trustworthy hub for global research cooperation.

From Crisis to Opportunity

The ongoing tariff war and the resulting reduction in U.S. science funding mark a profound realignment in the global research landscape. For researchers in America, the atmosphere is filled with uncertainty and unease. In Europe, the situation is being used as an opportunity to attract talent and strengthen its knowledge systems. For India, however, this disruption presents not just a challenge but potentially a defining moment of transformation.

If India responds with bold and strategic reforms, establishing world-class research clusters, offering globally competitive fellowship programs, strengthening engagement with its scientific diaspora, and fostering funding partnerships through public–private collaboration, it can shift its role from a traditional exporter of talent to an attractive global destination for scientific research.

The migration of researchers is not simply determined by the availability of visas or salary packages; it is shaped by the strength of ecosystems that ensure trust, stability, resources, and long-term opportunities. Should India succeed in building such an enabling environment, the present turbulence caused by tariff wars could become the catalyst for a historic transformation: positioning India as a central hub for global science and innovation in the 21st century.

From Frugal Innovation to Global Standards: India's Science Diplomacy in Low-Cost Technologies

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Introduction

India has earned global recognition for its ability to deliver cost-effective solutions without compromising on quality. From the Mars Orbiter Mission, achieved at a fraction of international costs, to the rapid distribution of vaccines during the COVID-19 pandemic, India has demonstrated that scientific ingenuity coupled with frugality can achieve scale and impact. Such innovations, born out of necessity, are now emerging as diplomatic assets.

Frugal innovation, broadly understood as “doing more with less,” has evolved in India into a framework of designing affordable, functional, and scalable solutions by optimising resources. For countries facing constraints of finance, infrastructure, or technical capacity, these solutions are not merely cheaper substitutes but lifelines that enable progress. Strategically deployed, frugal innovation is more than a domestic achievement—it is an instrument of science diplomacy, allowing India to project influence and build partnerships across the Global South while contributing to global goals such as the UN Sustainable Development Goals (SDGs).^{1,2}

Frugal Innovation and its Diplomatic Value

The roots of India's frugal innovation lie in its history of resource limitations. For decades, Indian laboratories operated with modest infrastructure, industries invested relatively little in R&D, and public spending on science rarely matched global averages. These constraints cultivated a culture of efficiency, adaptability, and problem-solving under pressure. What began as a compulsion has become a distinctive national capability.

For partner countries, this model has wide appeal. Many African, Southeast Asian, and Latin American nations face similar challenges: limited public health budgets, dispersed rural populations, and urgent needs in water, agriculture, and energy. By sharing frugal innovations, India signals solidarity and positions itself as a partner that provides affordable, context-sensitive, and scalable solutions rather than high-cost

technologies ill-suited to local realities. This makes frugal innovation not just a scientific or economic asset but also a diplomatic tool.

Healthcare Diplomacy: Vaccines and Diagnostics

India's pharmaceutical and biotechnology sectors are central pillars of its low-cost technology diplomacy. The country accounts for roughly one-third of the global vaccine market by volume, with pharmaceutical exports valued at US\$30.47 billion in 2024–25.^{3,4} During the COVID-19 pandemic, the Vaccine Maitri programme supplied 94 million doses to 94 countries and two UN agencies, an act of solidarity that enhanced India's credibility as a reliable health partner.⁵

The promise of healthcare diplomacy extends beyond emergencies. Indian companies produce affordable medicines for HIV/AIDS, tuberculosis (TB), and malaria, which remain endemic in parts of Africa and Asia. In TB, Indian molecular diagnostic platforms such as Truenat—endorsed by the World Health Organisation (WHO)—have been deployed across multiple countries, enabling early and accurate diagnosis in settings where conventional laboratory infrastructure is absent.⁶⁻⁸

This diplomatic footprint is expanding. In Africa, countries such as Nigeria, Ethiopia, Kenya, and Ghana are actively engaging with India on vaccine access and diagnostic collaborations. In Asia, Bangladesh, Nepal, Sri Lanka, and Cambodia have also benefited from Indian supplies and technical cooperation. The Serum Institute's plans to scale the R21 malaria vaccine to 100 million doses annually at a price of ~US\$4 per dose highlight how India can address diseases of the Global South at scale.⁹

Water as a Strategic Resource

Safe drinking water is another arena where India's innovations are gaining diplomatic relevance. Globally, 2.2 billion people lack safely managed drinking water.¹⁰ South Asia and Sub-Saharan Africa bear the brunt, with arsenic, fluoride, and bacterial contamination posing chronic risks. Indian scientists and entrepreneurs have developed low-cost arsenic removal plants, rapid testing kits, and nanobubble-based water rejuvenation technologies that are already in use within the country and piloted abroad.¹¹

For example, arsenic treatment units originating from Indian R&D have been introduced in Bangladesh and Nepal. Cambodia and Vietnam, grappling with arsenic belts in their groundwater, are potential partners for future deployments. In Africa, Ghana, Uganda, and Ethiopia represent opportunities where modular, community-level water treatment systems can be financed through Indian concessional Lines of Credit (LoCs). By exporting such solutions, India not only addresses health challenges but also builds long-term goodwill with governments and communities.

Agriculture and Energy Access

Food and energy security represent additional domains where frugal innovation intersects with diplomacy. In Sub-Saharan Africa, only 6% of cultivated land is irrigated.¹² This presents a significant opportunity for Indian micro-irrigation systems, solar-powered pumps, and drought-tolerant crop varieties. The International Solar Alliance (ISA), co-founded by India, now includes 107 member countries and has aggregated demand for over 276,000 solar water pumps.^{13,14} Indian firms supplying such pumps can play a pivotal role in Africa (Ethiopia, Kenya, Tanzania, Zambia) and small island states (Fiji, Comoros, Vanuatu) while contributing to climate resilience.

The energy dimension is equally pressing. Around 600 million Africans lack electricity, and the International Energy Agency estimates that US\$25 billion annually will be required to meet universal access goals by 2030.¹⁵ India's decentralised solar lanterns, mini-grids, and cold-chain

systems for vaccines and agriculture are well-suited to these contexts. Partnerships with Nigeria, Malawi, and Madagascar, supported by LoCs and ISA platforms, can scale such solutions in a financially sustainable manner.

From Low-Cost to High-Value: The Standards Imperative

Despite their potential, frugal technologies face barriers in global markets. Many are designed to meet Indian regulatory norms but not international standards such as ISO, CE, or WHO prequalification. This limits their exportability and reduces partner confidence.

Science diplomacy provides a way forward. India can negotiate joint certification programmes with regulators in Africa and ASEAN, allowing for concurrent reviews and reliance mechanisms. Embedding design-for-compliance into early-stage product development can ensure smoother adoption abroad. Equally important is India's active participation in global standards bodies, where it can advocate for protocols that reflect the realities of developing nations.

By aligning frugal innovation with global certification, India can shift perceptions from “low-cost” to “high-value,” positioning itself as a supplier of robust and reliable technologies.

Financing and Policy Instruments

Financing is critical to transforming innovations into diplomatic assets. India has already extended US\$32 billion in Lines of Credit across 68 countries¹⁶, with an additional US\$3.73 billion approved between 2022 and 2025.¹⁷ If directed strategically, these LoCs can serve as vehicles for deploying certified frugal technologies in partner countries.

Blended finance models, combining LoCs with multilateral funds, can derisk projects in water treatment, solar irrigation, and diagnostics. Outcome-based procurement—where payments are tied to health outcomes, litres of water delivered, or hours of irrigation—offers another way to build trust and accountability. Such approaches can ensure that frugal technologies are not only adopted but also sustained in the long term.

Markets and Projections

The potential impact of frugal innovation diplomacy is substantial. Pharmaceutical exports, already at US\$30.47 billion, could expand by US\$4–6 billion by 2030 if India strengthens its foothold in Africa and ASEAN.^{3,18} WHO-endorsed TB diagnostics such as Truenat could grow five- to seven-fold with pooled procurement across 25–30 countries.⁶⁻⁸ In solar irrigation, the global market is projected to reach US\$5.42 billion by 2033, and Indian firms could capture 8–10% of this share, translating to annual revenues of US\$430–540 million.¹⁹ Water testing and treatment, targeting communities without safe supply, could generate US\$0.5–1 billion annually in exports and services by 2030.^{10,11}

These projections illustrate that frugal innovation is not marginal; it is an economic and diplomatic force multiplier when coupled with certification and finance.

Challenges Ahead

Despite the promise, challenges remain. The perception of frugal technologies as “cheap substitutes” must be countered with evidence of durability, certifications, and lifecycle cost savings. Regulatory barriers—such as lengthy approval processes—require harmonisation efforts and mutual recognition agreements. After-sales service is often a weak link, but partnerships with local firms and regionally

based service hubs can address this. Geopolitical risks, such as tariff pressures on generics in the United States, highlight the need for diversification of markets.¹⁸

Conclusion

Frugal innovation is not only a story of doing more with less; it is about designing for inclusion, sustainability, and scalability. In the coming decade, countries that provide affordable, reliable health, water, agriculture, and energy solutions will hold both economic and diplomatic advantages. India, with its track record and scientific ecosystem, is well placed to be one of these leaders.

By embedding international standards, leveraging concessional financing, and targeting partnerships with Africa, ASEAN, and small island states, India can transform its reputation from a supplier of low-cost technologies to a trusted provider of high-value, globally relevant solutions. In doing so, frugal innovation will serve not only as a hallmark of Indian science but also as a powerful instrument of science diplomacy.

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Quantum Diplomacy: India's Position in the Global Race for Quantum Communication and Computing

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Quantum communication and quantum computing sit at the intersection of science policy and geopolitics. Quantum communication, especially quantum key distribution (QKD), promises information-theoretic security for key exchange, while quantum computing threatens today's public key cryptography and promises new capabilities in optimisation, materials, and AI acceleration. Both arenas demand standards, interoperability, and trusted supply chains —making them inherently diplomatic.

Two dynamics make the present moment decisive. First, the cryptographic transition has begun, the U.S. National Institute of Standards and Technology (NIST) has finalised the first post-quantum cryptography (PQC) standards, shaping global vendor and government adoption. Aligning with these standards is both a technical and diplomatic act because compatibility determines who can trade, interconnect, and certify.

Second, flagship demonstrations are shaping narratives. China's *Micius* satellite anchored the case for space-based QKD and intercontinental quantum links, signalling national capability, resetting expectations in international negotiations, and inviting coalition responses.

For India, with its track record of mission-mode execution (space, digital public infrastructure) and coalition-building with both advanced economies and the Global South, quantum technology is a natural arena to blend technical progress with strategic outreach.

India's Policy Architecture

The National Quantum Mission (NQM), approved in April 2023 with a budget of ₹6,003.65 crore through 2030–31, anchors India's efforts.¹ It targets the full stack, computing, communication, sensing, and materials. Beyond funding, the mission's explicit goal is to seed, nurture, and scale an ecosystem, specialised hubs, testbeds, and public–private partnerships that translate science into systems.

NQM sits atop a distributed institutional base: DST (mission stewardship), MeitY (compute and road-mapping), DRDO (defence applications), ISRO/Department of Space (free-space and satellite links), and leading academic centres (IISc, IITs, IISERs). This architecture matters diplomatically because it creates negotiating capital. India can bring deployable testbeds and market scale to joint pilots and standards, rather than offering only lab-scale results.

Quantum Communication: From Lab to Field

India's most visible gains are in free-space and fibre-based quantum communication, the part of the quantum stack closest to immediate national security and critical infrastructure use. In June 2025, DRDO and IIT Delhi demonstrated entanglement-based free-space quantum secure communication over >1 km distance, validating optics, pointing, synchronisation, and error-handling under real-world conditions.^{2,3} The official release frames it as a step toward quantum cyber security and future quantum networks. In 2024, DRDO reports also referenced entanglement distribution and QKD over ~8 km of optical fibre within IIT Delhi's campus, a complementary test that stresses interferometric stability and integrated control.

Though short of backbone scale, these results show India's capability to move from optics tables to field systems, paving the way for airborne and satellite relays. China's *Micius* satellite mission⁴ illustrates how one flagship project can reset diplomatic leverage, while Singapore's National Quantum-Safe Network (NQSN) shows how metro-scale pilots can anchor global credibility. India could achieve similar outcomes either independently or through coalition projects.

Quantum Computing: Ambition, Access, and the Long Game

On the compute side, India is pursuing a twin-track strategy to build indigenous hardware stacks while securing access diplomacy to near-term systems for talent training and algorithm development. The NQM and related government communications outline time-phased targets to build domestic systems in the tens to hundreds of qubits over the mission horizon, across platforms such as superconducting and photonic qubits. In parallel, public institutions have discussed a quantum computing reference facility to integrate with national HPC assets, an access point for researchers and industry to prototype algorithms as domestic hardware matures.

Membership in global networks and joint research with foreign vendors helps India bootstrap talent and benchmark algorithms without waiting for homegrown hardware to catch up. This dual approach is not a substitute for domestic capability, but it is a force multiplier. It shrinks learning cycles, improves curriculum relevance, and positions Indian teams to contribute to open-source tooling and error mitigation techniques that travel well across hardware. The diplomatic payoff is reciprocity: India becomes a meaningful contributor to the global quantum software commons, not only a consumer of hardware.

Alongside qubits, supply chains for cryogenics, detectors, and photonics are chokepoints. Prosaic as it sounds, supply-chain diplomacy, co-development agreements, vendor-qualification frameworks, and offsets in space/defence procurement can be as impactful as qubit breakthroughs in the near term.

Standards, Security, and the PQC Inflection

The cryptographic transition is the near-term battleground. In August 2024, NIST finalised Federal Information Processing Standards (FIPS 203/204/205), setting the de facto global baseline.⁵ Nations adopting them early can reduce "harvest-now, decrypt-later" risks while shaping global conformance tests. For India, aligning with NIST while creating India-specific profiles for Aadhaar, UPI, and national PKI would have a significant diplomatic impact across the Global South.

Notably, standards diplomacy is not just picking algorithms. It includes protocols for crypto-agility, migration schedules for sectors (telecom, power, finance), and hybridisation guidance (PQC + classical + QKD where justified). Publishing these as open playbooks, with reference implementations and procurement language, is a form of norm setting that aligns technological choices with India's broader role as a provider of digital public goods.

Comparative Landscape: Where India Stands

The United States, with algorithmic leadership via NIST and the largest commercial hardware ecosystem,

wields outsized influence over global quantum technology baselines, leveraging export controls and research security policies to define what can be shared internationally. For India, collaboration through mechanisms such as the Initiative on Critical and Emerging Technologies (iCET) working groups on quantum and telecom remains a diplomatic priority, enabling access to cutting-edge research, active participation in standards setting, and supply-chain stability.

The European Union's (EU) Quantum Flagship program, coordinating multi-billion-Euro investments and nurturing specialised industrial clusters such as photonics, presents a natural avenue for India to co-develop standards and establish interoperability labs, particularly in areas like QKD profiles and PQC deployments for critical infrastructure.⁶

China's achievements, most notably the *Micius* satellite and associated ground networks demonstrate early leadership in space-based quantum links and shape global strategic narratives.⁴ While India need not replicate China's path exactly, it can pursue coalition satellites and interoperable testbeds with partner nations to share costs, accelerate capability, and influence standards.

The United Kingdom's national quantum strategy, backed by long-term funding and a robust university–industry bridge, makes it a strong candidate for collaboration in device research and talent exchange, domains in which India can rapidly strengthen its position.⁷ Singapore's NQSN and NQSN+ projects offer a practical model for taking quantum-safe networking from concept to operational service, with active regulator participation and industry co-funding. India's metropolitan hubs could adapt this model to create live quantum corridors that serve as regional benchmarks.

In this global landscape, India's strengths lie in mission orientation, systems engineering capabilities derived from ISRO's heritage, and the scale of both its market and talent pool. The key gaps remain in space-based quantum links and the development of mid-scale domestic quantum computers, which can be addressed through targeted diplomatic initiatives and well-structured industrial partnerships.

Converting Technology into Diplomacy: Four Levers

India's quantum diplomacy can be advanced through four mutually reinforcing levers. First, standards and interoperability leadership offer a direct route to soft power through engineering. By convening and co-authoring QKD network interface profiles, India can align these efforts with PQC migration and crypto-agility principles. Hosting international plugfests and conformance testing events in India, backed by third-party certification, would position New Delhi as a gravitational center for the Global South seeking technical guidance and implementation models.

Second, joint demonstrators on both ground and space platforms can yield rapid gains. A collaborative small satellite QKD mission with Quadrilateral Security Dialogue (QUAD) or EU partners would produce three dividends: (a) hard technical learning in optics, precision pointing and key relay, (b) embedding shared standards directly into hardware and ground infrastructure, and (c) sending a strong symbolic signal of a trusted coalition in emerging technology. Domestically, establishing inter-city quantum-safe communication corridors, such as Delhi–Mumbai–Bengaluru, integrated with banks and telecom operators, could mirror Singapore's NQSN approach. These corridors could generate publishable playbooks, serving as practical models for replication in other countries.

Third, a nation-scale PQC migration program would allow India to lead by example. This would involve mandating comprehensive cryptographic inventories, prioritising the migration of high-risk systems with long data confidentiality lifetimes, and publishing sector-specific transition timelines. Providing reference implementations, standardised procurement templates, and tailored training for small and medium enterprises (SMEs) would not only secure domestic infrastructure but also create an exportable governance toolkit that partner nations could adopt.

Finally, talent and supply-chain compacts are essential to sustaining momentum. India can negotiate

reciprocal fellowship programs, establish joint intellectual property (IP) frameworks, and create attractive re-entry incentives for Indian researchers working abroad. On the hardware side, coupling defence and space procurement offsets with local manufacturing of critical quantum components, such as cryogenic systems, single-photon detectors, and advanced photonics, would strengthen domestic capacity. Coordinating trusted vendor lists with allied nations would further reduce embargo risks and ensure resilient supply chains in strategic technologies.

India's Recent Proof Points

India's recent advances in quantum communication provide tangible platforms for science diplomacy and technical collaboration. The DRDO–IIT Delhi free-space entanglement demonstration, achieving distances beyond 1 km, serves as a strong foundation for proposing air-to-ground or even air-to-air quantum link trials with international partners. Similarly, fibre-based entanglement demonstrations over ~8 km provide a practical sandbox for testing interoperability and key-management schemes essential for real-world deployments.

From a strategic funding perspective, the predictable eight-year envelope of the NQM allows India to plan recurring interoperability events and commit to multi-year co-development projects. Such long-term budgeting sends strong signals to potential partners, reassuring them of India's sustained engagement and reliability in joint quantum ventures. With the U.S. NIST's PQC standards finalised, India has an opportunity to brand itself as "quantum-safe by design", reinforcing its role as a trusted technology partner.⁸

The Diplomatic Theatre

India's quantum strategy gains significant strength through its network of minilateral and bilateral partnerships, which serve as both innovation platforms and diplomatic channels. The U.S.– India Initiative on Critical and Emerging Technologies (iCET) includes dedicated working groups on quantum and telecom, fostering alignment on standards and enabling structured research exchanges. In the near term, this collaboration can yield practical outcomes such as coordinated PQC roadmaps and mutually beneficial supply-chain agreements for critical components like cryogenic systems and quantum detectors, reducing deployment risks.

The QUAD working groups provide another powerful avenue for cooperation, particularly in developing joint pilot projects such as a QUAD small satellite QKD payload and establishing interoperability laboratories, long term infrastructure that can endure beyond political shifts. Similarly, the EU's Quantum Flagship ecosystem⁶ and the UK's National Quantum Strategy⁷ present India with valuable opportunities for collaboration in device physics, foundry access, and facilitating talent mobility through dedicated visa schemes.

Partnerships with ASEAN nations, especially Singapore, offer operational benefits by enabling replication of quantum-safe communication corridors similar to the NQSN, alongside exchanges on regulatory frameworks and commercial models. These collaborations are not symbolic but operational channels to secure market access and shape global governance.

A Playbook for India's Quantum Diplomacy

India can strengthen its global quantum diplomacy by leading decisively. It should:

- Lead PQC migration by example.
- Establish joint QKD demonstrators (ground and space).
- Create interoperability and certification labs.

- Negotiate talent reciprocity and secure supply chains.
- Export policy toolkits and training under a Quantum-Safe India brand.

Quantum progress will be incremental—not a single Sputnik moment but a chain of demonstrations, pilots, and standards. India has the ingredients: mission orientation, proof-of-concept field results, and pragmatic partnerships. The task ahead is to turn these ingredients into structured influence: (a) lead the crypto transition by example, (b) lock in interoperability through joint ground and space pilots, (c) become a certification and training hub for the region, and (d) build supply-chain resilience in the unglamorous but essential sub-systems.

If India executes on this playbook, its contributions will be felt beyond its borders, not only in qubits and key rates but also in the rules, norms, and trusted supply chains that shape the quantum era. That is quantum diplomacy in practice: science and engineering, scaled by partnerships, to build a secure and open future.

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Knowledge Diplomacy and the Ambassadors of Science

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Over recent years, a new concept has emerged alongside traditional diplomacy and its offshoot, science diplomacy – the idea of knowledge diplomacy. A 2024 report defines knowledge diplomacy as “*an umbrella term which covers a wide range of research, education, cultural and scientific collaborations that also serve a diplomatic purpose.*”¹ The Knowledge Diplomacy Project at the University of London Institute in Paris further distinguishes it from science diplomacy by “*its expansive scope, including scientific collaboration but also other forms of knowledge generation and exchange, such as social sciences, humanities, and professional education.*”²

This rethinking prompts us to reflect on the complex ways science and knowledge shape relationships across borders. In this context, India offers a particularly compelling case study.

India's Rising Scientific Power

India is rapidly emerging as a global science superpower. Despite relatively low public R&D spending, the country has made extraordinary strides. A 2024 *Nature* paper reports that “*in 2021–22, India had the world's third-largest pharmaceutical industry by volume and was the leading supplier of affordable medicines and generic drugs, some of which were crucial to fighting the COVID-19 pandemic worldwide. Last year, India became the fourth country ever to achieve a soft Moon landing and the first to land near the lunar south pole. It also has the world's largest constellation of remote-sensing satellites. India is among the world's most prolific countries in terms of research output, after the United States and China. From 2014 to 2021, the number of universities increased from 760 to 1,113.*”³

These achievements have not gone unnoticed. Increasingly, British universities view India not just as a place to recruit students, but as a long-term partner in education and research. The University of Southampton opened a campus in Delhi in 2025, while others—including the University of Liverpool, University of York, Newcastle University, Coventry University and Queen's University Belfast—have announced or approved plans to establish campuses in India. Such initiatives deepen partnerships and expand the exchange of knowledge.

The UK–India Research Partnership

For the UK, India is more than an emerging partner; it is already central to international research

collaboration. UK Research and Innovation (UKRI), the UK's largest public funder of research and innovation, has jointly supported nearly £400 million worth of research and innovation programmes with the Government of India over the past 15 years.

In 2024, UKRI announced a £7 million collaboration on telecoms research under the UK-India Science, Technology and Innovation Partnership⁴, and in 2025, joined with the British High Commission and Indian colleagues to celebrate the International Day of Women and Girls in Science.

From telecoms and sustainable manufacturing to tackling farmed animal diseases and understanding geohazards, and driving innovation in sustainable materials, manufacturing and power electronics, the India-UK partnership is an example of how countries can collaborate for their own advantage but also for global good. India has the world's second-largest telecommunications network, and innovations in equity of access to digital services, improved rural coverage and connectivity, lower costs of deploying network infrastructure, and secure, cost-effective digital services at scale will have direct benefits for India, but the lessons learned can also shape global digital inclusion.

Lessons from India's Interdisciplinarity

As a member of the Governing Board of the Global Research Council, I have seen firsthand how the principles of Open Science, equitable partnerships and the pursuit of the Sustainable Development Goals unite scientists and provoke collaborations above and beyond political and economic ties. Trade deals can be valuable components of international diplomacy, and offer opportunities to manage regulatory differences, but it is curiosity—the human drive to learn, teach, discover and communicate—that sustains scientific diplomacy.

There are generic truths about the importance of scientific exchange, but each bilateral collaboration is shaped by the values of participating countries, their complementary strengths and epistemological methodologies. Understanding each other's paths to discovery is often as important and exciting as the discovery itself.

In this respect, India offers valuable lessons. A recent article in the *New Indian Express* highlighted how leading Indian Institutes of Technology are weaving the arts, humanities and social sciences into their STEM programmes. *"For decades, STEM disciplines were measured by quantifiable outputs: patents, products, and market impact. But that feels increasingly small in the wake of climate change, AI ethics, and social disconnection. Hence, the questions we face today are not only scientific; they are also social, cultural, and moral. What is emerging within these IITs is a conscious reframing for seeing code and computation in the larger context of history, ethics, language, and social practice."*⁵

The UK could learn much from this reframing. Arts and humanities can serve as translators and cultural brokers—helping societies reimagine the future by drawing on history, ethics, and collective imagination. Just as we need science embassies between nations, perhaps we need knowledge (science) embassies between disciplines.

Here the long tradition of Indian knowledge is fascinating and deeply intertwined with notions of connectivity. Recent attention on the Silk Roads illustrates the role of trade and material exchange in fostering and accelerating the exchange of ideas. The Silk Roads carried not only goods but also ideas—religious, artistic, political, and scientific. The Indian subcontinent was a crucial hub in this east-west exchange, as William Dalrymple illustrates in *The Golden Road*, and as India's Foreign Minister S. Jaishankar emphasises in *The India Way*.

This spirit of interconnectedness is deeply embedded in Indian thought. The subcontinent has given rise to Hinduism, Buddhism, and Jainism—traditions that are diverse yet united by a fascination with nature, ethics, and human flourishing. Such plurality fosters a worldview that is comfortable with multiplicity and open to integration—a perspective the world sorely needs today.

Towards Equitable Collaboration

Two key points arise. First, India should not be seen merely as an object of interpretation but as a partner with agency, one with whom we must co-curate narratives and equitable representations of heritage. Second, collaborations should not be confined to Western-prioritised technologies; they must also embrace India's civilisational traditions of ethics, community, and sustainability. Societal change requires patient engagement with moral and cultural questions; something we must embed in our cofunding strategies if they are to be both genuinely equitable and effective.

This scientific interdisciplinarity spirit is evident in Sunil Khilnani's *Incarnations: A History of India in 50 Lives*, which traces the questing mind of King Ashoka in the third century CE to the restless intellect of Rabindranath Tagore, thinkers who looked beyond disciplinary boundaries, combining science, spirituality and society in pursuit of broader truths.

I close with an example that symbolises my theme: Panini's *Ashtadhyayi*. Written in the fourth century BCE, this remarkable linguistic treatise distilled the workings of Sanskrit into a system so rigorous that it remains relevant today. Recitable in two and a half hours, yet spanning 1,300 pages in its latest English translation, it exemplifies the power of compression, structure and analysis. By making Sanskrit a lingua franca of the East—much as Latin was in the West—Panini laid intellectual foundations that still underpin coding and computational thinking today. This is the essence of knowledge diplomacy: rooted in culture, expressed through science, and projected into the future.

Conclusion

Knowledge diplomacy, like science diplomacy, takes many forms. It can pursue strategic advantages, sovereign capability or specific technological goals. But its greatest value lies in fostering deeper, more meaningful partnerships that integrate diverse ways of knowing. For the UK and India, the path forward is rich with possibilities. It is a relationship which will become deeper and more meaningful if we learn to think with each other's mental apparatus and see the world through each other's eyes. If that means that UK learns from India about their values of plurality, interconnectedness and interdisciplinarity—where arts and humanities enrich technology and the past informs a sustainable future—then we will become better scientists and partners.

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MoUs Signed //////////////////////////////////////

India and Maldives Sign MoU to Boost Bilateral Cooperation in Fisheries and Aquaculture

India and the Maldives signed a MoU in July 2025 to enhance bilateral collaboration in fisheries and aquaculture. The agreement focuses on promoting sustainable tuna and deep-sea fisheries, strengthening aquaculture and resource management, fostering fisheries-based eco-tourism, and advancing scientific research and innovation. Key areas of cooperation include value chain development, mariculture advancement, trade facilitation, and capacity building. The MoU will also support the Maldives in expanding fish

processing capabilities through investments in cold storage, hatchery development, and the diversification of cultured species. In addition, training and knowledge exchange programmes will be facilitated in aquatic animal health, biosecurity, aquaculture farm management, and specialized technical fields such as refrigeration and marine engineering. This partnership reflects a shared commitment to building a resilient, innovative, and sustainable future for the fisheries sector.

India And Bhutan Sign MoU on Technical Cooperation in Agriculture and Allied Sectors

In August 2025, India and Bhutan signed a MoU in Thimphu to further strengthen cooperation in agriculture and allied sectors. The MoU marks an important milestone in the enduring partnership between the two countries, reflecting their shared commitment to food security, sustainable farming, and rural prosperity. The agreement provides a framework for collaboration in agricultural research and innovation, livestock health and production, post-harvest management, value chain development, and the exchange of knowledge,

skills, and expertise. To operationalize the MoU, the first session of the Joint Technical Working Group (JTWG) was convened immediately after the signing, where both sides adopted the Terms of Reference and identified priority areas for early action. The discussions covered a wide range of cooperation, including agriculture, livestock, marketing and cooperatives, food processing, seed sector, research and technology, and capacity building.

Announcements //////////////////////////////////////

DUO-CIMEA/Italy Fellowship Programme

Submission deadline: 31 October 2025

Further information at:

<https://www.cimea.it/pagina-duo-cimea-italia>

Carl-Zeiss-Humboldt Research Award

Submission deadline: 24 December 2025

Further information at:

<https://www.humboldt-foundation.de/en/apply/sponsorship-programmes/carl-zeiss-humboldt-research-award>

EMBO Scientific Exchange Grants 2025

Submission deadline: Throughout the Year 2025

Further information at:

<https://www.embo.org/funding/fellowships-grants-and-career-support/scientific-exchange-grants/benefits/>

JSPS International Fellowships for Research in Japan

Submission deadline: 28 April 2026

Further information at:

https://www.jsps.go.jp/file/storage/j-fellow/j-fellow_14/application_requirements/2026/2026_applicationguideline_e.pdf

New Publications //////////////////////////////////////

Ali H, Agha A, Khaliq M, Nasir M, Ullah A, Riaz I, Aziz M (2025) **The role of nuclear technology in international relations: Implications for global security, energy policy, diplomatic power, and strategic stability.** *Scholars Journal of Arts, Humanities and Social Sciences*, 13(8): 237–268. <https://doi.org/10.36347/sjahss.2025.v13i08.006>

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Call for Proposals //////////////////////////////////////

CSIR-DAAD - Call for Proposals for the Bilateral Exchanges of Scientists/Academics

Last Date: October 07, 2025

Further information at: https://www.csir.res.in/sites/default/files/2025-07/csir-daad_2025_0.pdf

DST-Inria Targeted Programme

Last Date: October 16, 2025

Further information at: <https://www.inria.fr/en/call-for-projects-international-partnerships-associate-teams-2026>

CSIR-EU MSCA-Staff Exchanges_Call_2025

Last Date: October 17, 2025

Further information at: https://www.csir.res.in/sites/default/files/2025-04/csir-eu_msca-se_call_2025_guidelines_and_announcement_3.pdf

India-Canada Collaborative Industrial Research & Development Programme 2025

Last Date: October 17, 2025

Further information at: <https://tdb.gov.in/canada>

BRICS STI Framework Programme Innovation Call 2025

Last Date: November 5, 2025

Further information at: <http://brics-sti.org/index.php?p=new/40>

India-Sweden Collaborative Industrial Research & Development Programme 2025

Last Date: November 14, 2025

Further information at: <https://tdb.gov.in/launch-india-sweden>

Forthcoming Events //////////////////////////////////////

Bridging Frontiers: Science, Diplomacy & Innovation for a Sustainable Future

Date: November 4-6, 2025

Further information at:
<https://genevanations.ch/upcoming-conference/>

2nd European Science Diplomacy Conference: Bridging divides in a fragmented world

Date: December 17-18, 2025

Further information at:
<https://www.science-diplomacy.eu/news/save-the-date-2nd-european-science-diplomacy-conference-bridging-divides-in-a-fragmented-world/>