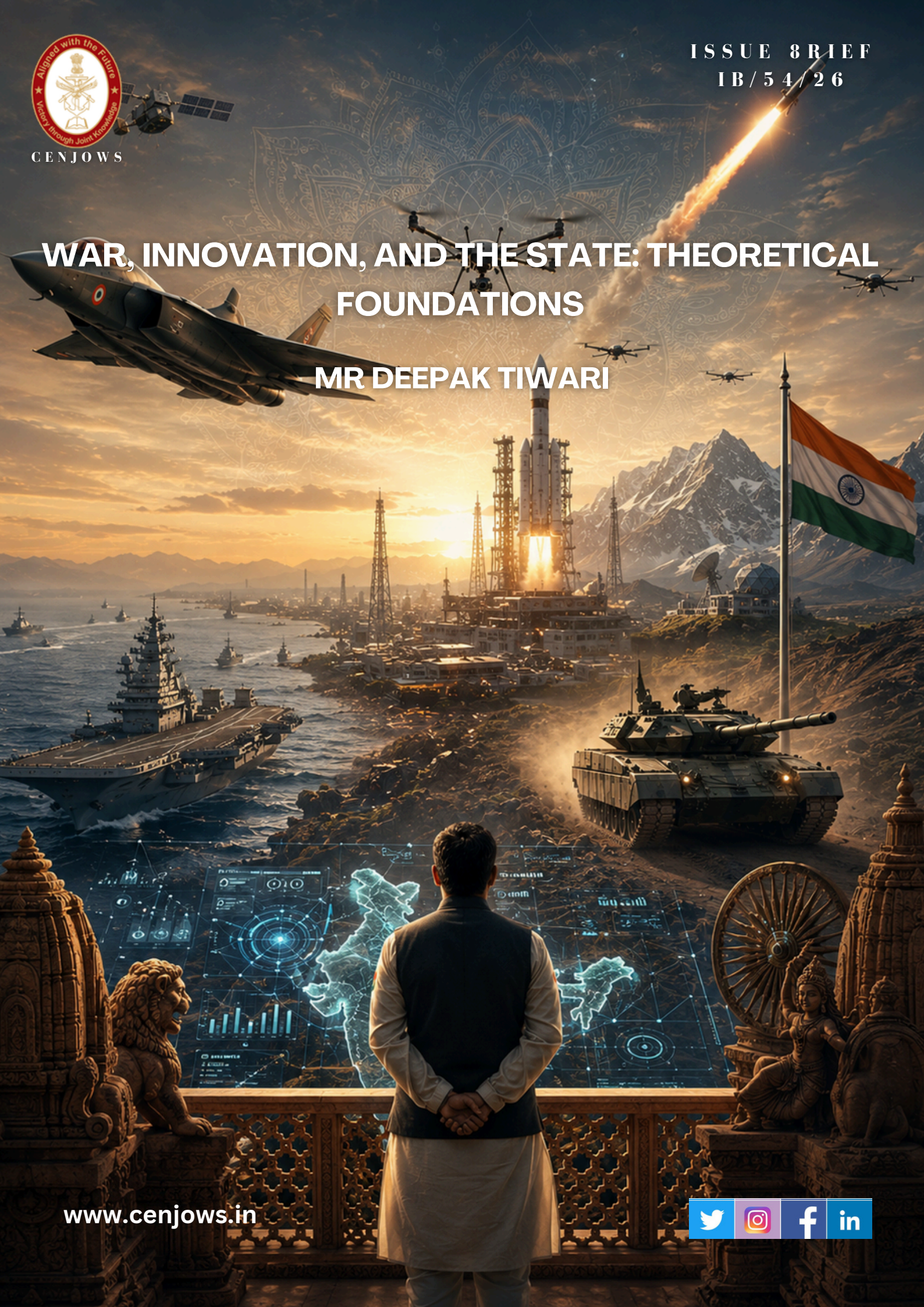
CENJOWS

ISSUE BRIEF
IB/54/26

WAR, INNOVATION, AND THE STATE: THEORETICAL FOUNDATIONS

MR DEEPAK TIWARI



www.cenjows.in

CENTRE FOR JOINT WARFARE STUDIES

CENJOWS

War, Innovation, and the State: Theoretical Foundations

Mr Deepak Tiwari is a technical research assistant at CENJOWS

"War has names, some fall short, plenty are same
It's the precursor to peace, to order and the question of restrain.
War has kins, they are death and destructions, and not its sins
It's a cycle of creation, as men makes war and war makes men."

- Author

Introduction

There is a peculiar silence at the heart of innovation studies. In the corporate-civilian domain, the geography of technological evolution has been mapped by decades of scholarship with remarkable precision. Yet the oldest, most consequential, and most generously funded innovation system in human history receives surprisingly thin theoretical attention. The system of innovation that gets prioritised over everything and keeps the resources of an entire nation at its disposal is the one to organise a State's efforts to develop superior instruments of violence. In simple words, defence innovation has yet to remain a highly neglected area while exploring theoretical underpinnings similar to those that exist in the socio-politico-economic domain.

This silence is not accidental. Defence innovation sits at the intersection of two domains that modern academic disciplines prefer to keep separate; these are the

economics of knowledge and the politics of force.[1] Innovation economists are generally uncomfortable with the strategic logic that animates military research and development. Security studies scholars, conversely, rarely engage with the institutional economics of how defence capabilities are actually produced. The result is a literature full of sophisticated partial accounts: innovation theory that treats defence procurement as a peripheral distortion of market dynamics and strategic studies that take technological capability largely as given rather than as something produced through specific institutional arrangements.

This article is an attempt to close that gap, not in the abstract, but in a specific historical and institutional context that makes it more significant. India presents perhaps the most instructive contemporary case of a large, strategically ambitious state struggling between technological dependence and the aspiration for sovereign defence capability. For seven decades since independence, India has maintained one of the world's largest defence establishments while simultaneously importing the overwhelming majority of its most critical military platforms.[2] The paradox is not a puzzle of will or resources since India has expended both generously, but it is the protracted failure of institutional design.

This article attempts to provide a theoretical scaffolding for the missing narrative and gaps in understanding. It does so by taking seriously a proposition that sounds simple but proves surprisingly generative. The proposition is that defence innovation is not a variant of civilian innovation, and theories designed to explain civilian innovation will systematically mislead if applied without modification to the defence context. The differences are not merely of degree, but they are structural. A single buyer who is also the sovereign, the monopsonist state, shapes the innovation incentive landscape in ways that no competitive market model can capture. Secrecy regimes that are essential to strategic effectiveness simultaneously sever the knowledge-diffusion mechanisms that drive civilian innovation ecosystems. The objective function that does not ascribe to profit maximisation but strategic advantage under existential uncertainty produces a logic of redundancy, worst-case planning, and tolerance for cost. Such a system may look like a dysfunction through a market lens, but it is entirely rational through a security lens.

The article proceeds through four theoretical traditions that between them define the intellectual landscape of defence innovation scholarship. It begins with Schumpeter, not because his framework fits perfectly, but because the concept of creative destruction, properly understood, captures something irreducibly true about how military technological revolutions unfold. It then moves to the military-industrial complex tradition and the RAND Corporation discourse that gave it analytical rigour. It encapsulates a body of work that remains indispensable for understanding how institutional capture, cost-plus contracting, and procurement pathology become the default equilibrium of sustained state-defence-industry relationships.[3] The third tradition, the Revolution in Military Affairs (RMA) literature, introduces the crucial insight that technology alone is not capability: the organisational and doctrinal transformations required to exploit technological change are the hardest, slowest, and most politically fraught part of military innovation. The fourth, the National Innovation Systems framework of Lundvall and Freeman, shifts the unit of analysis from the firm or the procurement programme to the institutional ecology.[4] This framework provides the web of relationships between research organisations, industry, educational institutions, and the state, within which innovation either flourishes or diminishes.

What emerges out of this scaffolding is a composite theoretical lens rather than a single master framework. No unified theory of defence innovation exists, nor should we expect one since the phenomenon is too historically variable, too institutionally contingent, and too geopolitically inflected to yield to a single model. What the traditions collectively provide is a set of analytical questions precise enough to generate real insight which can be applied to the Indian case. The questions that thus arise and can be answered are, who bears the risk and who captures the reward? What institutional ecology is necessary for capability to accumulate rather than dissipate? Where is the technological frontier, and is India building toward it or away from it? And finally, what would it actually mean for India to be strategically self-reliant, not merely in the rhetorical register of policy, but in the deeper sense of possessing the institutional capacity to sustain innovation through successive generations of military technology?

The Foundational Provocation

War is the most wasteful human activity imaginable, and yet it is the most powerful generative force in the history of knowledge. The internet, GPS, radar, nuclear power, jet engines, synthetic rubber, and the digital computer, the lineage of transformative general-purpose technologies runs directly through state-funded, war-driven programmes. This is not incidental but structural. The development of radar in Britain between 1935 and 1940 is perhaps the closest early example of how military urgency produces technological transformation that would have been impossible under peacetime conditions. The underlying physics of radio wave reflection had been understood since Heinrich Hertz demonstrated the phenomenon in 1886. For nearly five decades, it remained a scientific curiosity, insufficiently funded, insufficiently prioritised and insufficiently integrated with the engineering and manufacturing capabilities that would make it operationally useful.[5] The history of the digital computer as well, at every decisive moment, is also a history of military funding and military urgency. Alan Turing's foundational work on computability and the theoretical architecture of universal computing machines, or the US reaching out on a different trajectory with their Electronic Numerical Integrator and Computer (ENIAC), were both progressively funded by their defence establishment and were war-driven in one way or other.[6] In all such countless cases, what changed was not the science but the institutional context within which the ensuing technological milestone was just a file away.

The question this analysis must answer before introducing any theoretical tradition is, ‘why does organised violence produce organised knowledge?’ And more pointedly, who controls that knowledge, and on what terms does it escape into the wider world? These questions are not merely academic. They bear directly on how we understand innovation policy and on why some nations develop technological capacity that compounds across generations while others remain permanently dependent. The matter of research, thus, appears to be picturing the autonomous defence innovation system in a country like India, or anywhere else that has inherited technological dependence as a structural condition.

Why Civilian Innovation Theory Is Insufficient

Before the discussion takes a dive into the vast ocean of theories, it is worth pursuing to understand how defence innovation is categorically different from civilian innovation. Since most of the canonical theories have been designed to explain innovation systems from a corporate capitalisation perspective, they remain fundamentally inadequate to deliver any meaningful insights in the domain of military innovation. The innovation system followed in a highly securitised domain, such as defence, has some inherent constraints. Three core such constraints, which have remained fundamental in every country and have proved a steep fall in the case of India, have been discussed as follows:

- **The Monopsony Problem:** In civilian markets, companies have a large buyer base which can be further expanded both horizontally (market diversification) and vertically (market penetration). These corporate firms always remain in perpetual competition to acquire more markets for their products and services. In defence, however, there is almost always one buyer, the state. This structure of a single buyer shapes what technologies to develop, on what specifications, and which other players can be involved, on top of the price distortion. Over the time, the state direction starts to shape their behaviour and dictates whether these private or public firms will ever be able to develop the autonomous capability to innovate. India, through its decades-long Defence Research and Development Organisation (DRDO) – Defence Public Sector Undertakings (DPSUs) ecosystem, presents a near-perfect laboratory for observing what happens when monopsony becomes permanent. In its experience, technological capability is captured inside state institutions, private industry is crowded out for generations, and the feedback loops are severed between operational experience and strategic R&D.
- **The Secrecy Problem:** Normal innovation theory assumes that knowledge diffuses. Patents eventually expire. Researchers move between firms. Tacit knowledge travels with engineers. But defence knowledge is systematically suppressed. Classification regimes, export controls, and compartmentalisation mean that the spillovers that drive civilian innovation ecosystems, the reason Silicon Valley clusters geographically, and the reason pharmaceutical ecosystems concentrate near research universities, are actively prevented in

defence. This is not a market failure. It is a policy choice with second and third-order consequences that take decades to appear.

- **The Strategic-Imperative Problem:** Civilian firms optimise for profit, market share, or survival. Defence innovation is optimised for a different objective function entirely: not losing a war that is yet to happen with an adversary whose future capabilities are unknown. This produces a logic of redundancy, worst-case planning, and tolerance for inefficiency that makes no sense through a market lens but makes perfect sense through a security lens. The F-35 programme's cost overruns are not a failure by defence procurement standards, but they are the price of maintaining a production capability that can be surged in a genuine crisis.

  These three peculiarities are the reason that no single theoretical tradition is adequate to the task. Each of the traditions introduced below illuminates one dimension while leaving others in the dark.

The Four Theoretical Traditions-Properly Situated

- **Schumpeterian Innovation: The Engine Without a Steering Wheel**

  Schumpeter gave us the most powerful metaphor in innovation theory: creative destruction. The economy advances not through smooth optimisation but through violent discontinuities, new combinations of knowledge, capital, and organisation that annihilate the existing order. The entrepreneur is the agent of disruption; the large firm, eventually, is the bureaucratised shell that the next wave of disruption sweeps away. Schumpeter's framework applies to defence in two powerful ways and fails in one decisive way.

  It applies because military history is, in a deep sense, a history of creative destruction. Gunpowder destroyed the medieval castle-knight complex. The machine gun destroyed Napoleonic linear infantry. Carrier aviation destroyed the battleship as the capital instrument of naval power. The precision-guided munition complex, GPS guidance, stealth and real-time ISR are in the process of destroying the large armoured formation as the decisive instrument of land warfare. These are not incremental improvements. They are Schumpeterian discontinuities in the means of organised violence.

It also applies because the Schumpeterian framework for the large firm, which he called ‘Mark II Schumpeter’, the shift from individual entrepreneurs to corporate R&D laboratories, maps remarkably well onto the defence-industrial complex. Lockheed's Skunk Works, the RAND Corporation, and the Defence Advanced Research Projects Agency (DARPA) are institutionalised creative-destruction machines, funded by the State to deliberately obsolete existing systems.[7]

But Schumpeter's framework fails at the crucial juncture of who bears the risk and who captures the reward. In civilian innovation, entrepreneurs risk private capital for private gain. The mechanism of creative destruction is disciplined by profit and loss. In defence, the state bears most of the risk, funding basic research, absorbing development failures, and guaranteeing procurement while private contractors capture the reward. This is not Schumpeterian entrepreneurship. It is risk socialisation and profit privatisation. India's attempts to build a defence private sector have consistently foundered on this asymmetry, where private firms are asked to take Schumpeterian risks but within a procurement environment that offers none of the Schumpeterian rewards.[8]

- **The Military-Industrial Complex: Eisenhower's Warning as Social Theory**
  When Dwight Eisenhower warned in 1961 of the "military-industrial complex (MIC)", he was not merely making a political observation. He was articulating a structural theory of how organisations that benefit from the threat of inflation will systematically create the conditions for their own continuation.[9]

  The RAND Corporation's discourse, the body of strategic theory produced in the 1950s and 1960s by Brodie, Wohlstetter, Kahn, and their collaborators, is essential reading for anyone who wants to understand why defence innovation diverges so sharply from civilian innovation. RAND pioneered systems analysis as a method: the quantitative comparison of weapons systems on cost-effectiveness grounds. It brought the rigour of operations research to strategic choice.[10] In doing so, it created an intellectual framework that simultaneously demystified defence procurement and gave unprecedented power to the technocrats who wielded the method.

The MIC framework, as it evolved in political science and political economy, identifies several dynamics that are directly relevant to India's situation. The revolving door between government, military, and industry creates structural incentives for programmes that are difficult to terminate, procurement specifications that are impossible for new entrants to meet, and an institutional culture that prizes continuity over disruption. India's DPSUs Hindustan Aeronautics Limited, Ordnance Factory Board and Bharat Earth Movers Limited (BEML) exhibit these pathologies acutely. They are organisations built to perpetuate themselves, not to innovate.[11]

The cost-plus contract as a cultural artefact deserves special attention. When firms are reimbursed for actual costs plus a guaranteed profit margin, they have no incentive to economise or innovate in ways that reduce costs. They have every incentive to maximise cost.[12] The Tejas Light Combat Aircraft programme, which ran for over three decades before achieving initial operational clearance, cannot be understood without this lens. It is not primarily a story of technical failure. It is a story of a procurement system that provided no disciplining mechanism against cost overruns, schedule slippage, or requirements creep.

- **Revolution in Military Affairs (RMA): Technology as Doctrine**

  The RMA literature, which peaked in the 1990s following the Gulf War's demonstration of precision warfare, makes a claim that sits at the intersection of history, strategic theory, and organisational sociology: the transformation of military capability requires not just new technology but also new doctrine and new organisational forms to exploit it.

  Andrew Marshall at the Pentagon's Office of Net Assessment, along with strategic theorists like William Lind (Manoeuvre Warfare), Martin van Creveld (transformation of war), and Michael O'Hanlon (technological change and the future of warfare), developed a framework with several key propositions. First, military effectiveness is a multiplicative function of technology, doctrine, and organisation, not simply additive. Second, the ability to exploit a technological revolution requires dismantling existing organisational structures, which creates enormous bureaucratic resistance. Third, the state that successfully navigates

an RMA gains an asymmetric advantage that lasts until its adversaries close the gap.

For India, the RMA lens is illuminating and frustrating. India's military has acquired significant modern platforms such as the Rafale, the S-400, and advanced submarine and surface combatant designs. But the doctrinal and organisational transformations required to exploit their network-centric warfare, integrated theatre commands, and ISR-strike integration capabilities have lagged by a generation. The Integrated Theatre Commands debate, which dragged on for years before gaining traction, is a case study in the institutional resistance that the RMA literature predicts.

The RMA framework also highlights a particularly painful aspect of India's situation: late-mover disadvantage in military technology. Unlike civilian technology, where imitation is often a viable catch-up strategy (as East Asian industrialisation demonstrated), military RMAs create capabilities that cannot simply be purchased off the shelf. The tacit knowledge embedded in an advanced fighter pilot's training, a submarine crew's operational culture, or a special forces unit's integration practices takes decades to develop. India's import-heavy procurement strategy has meant that much of this tacit knowledge has not been transferred or indigenously developed.

- **National Innovation Systems: The Ecology of Capability**

  The NIS framework, developed independently by Christopher Freeman (studying Japan), Bengt-Åke Lundvall (theorising the knowledge economy), and Richard Nelson (comparing industrial research across countries), makes a fundamental move that the other three traditions largely avoid: it situates innovation in institutional ecology rather than market dynamics.

  The core argument is that the rate and direction of innovation in any economy depends on the relationships between firms, universities, government agencies, financial institutions, and cultural norms about knowledge-sharing, risk-taking, and collaboration. You cannot understand Japan's post-war industrial success without understanding the Ministry of International Trade and Industry (MITI)’s coordination role, the Keiretsu networks, and the technology

transfer agreements that structured learning. You cannot understand the United States' innovation system without understanding the role of the research university, the venture capital industry, and the defence procurement system in co-producing the knowledge base that both civilian and military technology draws on.

For a book on India, the NIS lens is arguably the most productive. India's national innovation system exhibits a specific structural pattern: world-class islands of excellence embedded in a sea of institutional weakness. The IITs produce exceptional engineers. DRDO and the Indian Space Research Organisation (ISRO) have demonstrated genuine advanced technical capability in specific domains. The Indian Institute of Science (IISc) and Tata Institute of Fundamental Research (TIFR) have produced Nobel-calibre science. But the connective tissue between these islands, the technology transfer mechanisms, the industry-university interface, and the venture ecosystem for deep-tech defence startups are thin or absent.

This is why India's defence indigenisation has repeatedly failed to produce what policymakers expected. Procuring technology from abroad without building the institutional ecology to absorb, modify, and eventually surpass it, reproduces dependency rather than eliminating it. The NIS framework predicts this outcome precisely, further suggesting that Atmanirbhar Bharat, however well-intentioned, will fail if it focuses on mandating indigenous content percentages without building the institutional ecology that makes indigenous content meaningful.

The Mazzucato Turn: Mission-Oriented Innovation and the Entrepreneurial State

The most consequential theoretical intervention in innovation policy over the past two decades has not come from economics departments or business schools. It has come from a political economist willing to ask a question that neoliberal orthodoxy had rendered unanswerable. The question was, what if the State is not merely a corrector of market failures but the primary architect of the markets that matter most?

Mariana Mazzucato's reconceptualisation of the State's role in innovation, developed in her book “The Entrepreneurial State”, is best understood as a historically grounded challenge to a specific and influential misreading of how transformative technologies actually come into existence. For three decades following the Reagan-Thatcher settlement, the dominant framework in innovation policy treated the State's role as residual and corrective. The state’s role was marked to step in where markets fail, provide basic science funding that private firms cannot appropriate, and then withdraw to allow competitive markets to do the work of development, diffusion, and commercialisation.[13] The discourse kept the state at the backstop, the entrepreneur as the hero, and the venture capitalist as the true engine of technological progress. Mazzucato's empirical demolition of this narrative is, as she herself has noted, devastating in its simplicity.[14] The technologies that define the smartphone, the device that became the symbol of private-sector innovation genius, are, without exception, traceable to public investment. The internet originated in ARPANET, funded by the US DARPA. GPS was developed and is operated by the US Department of Defence. The touchscreen interface emerged from research at the European Council for Nuclear Research (CERN) and the University of Delaware, funded by public science grants. The voice recognition underlying Siri was developed at SRI International on a DARPA grant. Lithium-ion battery chemistry was developed at Binghamton University and Oxford, funded by the US Department of Energy and UK public science bodies.[15] The microprocessor architectures that make the device function trace their lineage through decades of military procurement that underwrote semiconductor scale-up when no commercial market existed to justify the investment. Apple, a genuinely innovative firm, combined, miniaturised, and designed these publicly funded technologies into a product of extraordinary commercial success. But the foundational knowledge was not Apple's creation. It was the public's, produced at public expense, and transferred on extraordinarily favourable terms to private firms that captured the financial returns while the public retained the risk.[16] The theoretical move that Mazzucato makes based on this evidence is precise and important. It is not that states are better innovators than firms; they are not, and the history of state-owned enterprise contains as many cautionary tales as the history of private monopoly. The move is rather that the relevant distinction is between different types of uncertainty and that states and markets have systematically different capacities to bear them. Fundamental technological uncertainty, the uncertainty that attaches to basic research, to the development of

genuinely novel capabilities without established markets, and to the long time horizons between scientific discovery and commercial application, is uncertainty that private capital markets are structurally ill-equipped to absorb. Not because private investors lack imagination, but because the accountability mechanisms of private capital, quarterly reporting, fiduciary duty, and the requirement to demonstrate returns within investment horizons measured in years rather than decades are incompatible with the patience that frontier research demands. The state, as the one institution with genuinely long-term horizons and the capacity to socialise risk across the entire population, is not substituting for the market at the frontier. It is doing something the market cannot do and performing a function that the market-failure framing systematically obscures by treating it as an unfortunate necessity rather than a core institutional competence. For defence innovation theory specifically, Mazzucato's framework performs two operations that the existing literature has been unable to accomplish simultaneously. The first is rehabilitation, where it establishes that state-directed innovation at the technological frontier is not merely a second-best response to private market failure but can be the primary locus of transformative capability development. This matters particularly for India, where the policy conversation about DRDO's chronic underperformance has been dominated by a single prescription to introduce private competition, which is necessary but structurally insufficient. If the problem were merely DRDO's insulation from competitive discipline, private competition would solve it. But the deeper problem is that no Indian private firm can rationally bear the costs, time horizons, and fundamental uncertainties of frontier defence R&D investment. India's private defence sector is not reluctant to innovate. It is rationally responding to an environment in which the public institutions that should be bearing early-stage risk are not doing so effectively and in which the returns to private innovation investment in defence remain uncertain, delayed, and subject to procurement unpredictability. Introducing competition at the wrong stage of the pipeline is not a solution to this problem. It is a restatement of it in market vocabulary. The second operation is definitional: Mazzucato's mission-oriented framework provides precise criteria for distinguishing between a genuine innovation mission and a procurement programme wearing mission language. A mission, the Apollo programme, DARPA's original mandate, and the EU's current Horizon missions have characteristics that distinguish them structurally from procurement.[17] It is defined by a problem to be solved rather than a system to be acquired. It tolerates and expects

failure in individual projects while maintaining portfolio diversity across competing approaches. It is explicitly designed to produce new technological capabilities that outlast and exceed the original mission objective. And it measures success not by whether a specific platform was delivered on time and on budget, but by whether it created a new frontier of capability that subsequent actors, public and private, can build upon. India's defence innovation programmes have, with few exceptions, been procurement programmes in mission disguise. They have been defined by platform specifications, measured by delivery milestones, terminated when budgets are exhausted rather than when capabilities are established, and leaving behind little institutional knowledge that survives the specific programme.[18] The Tejas programme produced an aircraft. It did not produce an Indian aerospace innovation ecosystem. The distinction is precisely what the mission-oriented framework illuminates. The framework also reframes, with uncomfortable clarity, the question of why India's defence innovation system has not served the catalytic civilian function that DARPA served in the United States.[19] DARPA's most consequential contribution was not the weapons systems it produced but the technological capabilities, packet-switching, the graphical user interface, advanced materials, and the architectural foundations of autonomous systems.[20] India's DRDO has produced no comparable civilian spillovers, and the reasons are structural rather than accidental. Classification regimes that are more restrictive than necessary have prevented knowledge diffusion. Institutional walls between the DRDO and the civilian R&D ecosystem between defence laboratories and the IITs, the IISc, and the emerging deep-tech private sector have prevented the cross-pollination. Moreover, the technologies developed have too often been below the global frontier, producing indigenised versions of capabilities that other countries mastered a generation earlier rather than advancing the frontier in ways that would generate genuinely novel civilian applications.[21]

The Dual-Use Question: Spin-Off, Spin-On, and the Blurring Frontier

The concept of dual-use technology with both military and civilian applications has undergone a quiet but profound inversion over the past thirty years. During the Cold War, the dominant pattern was spin-off, where technologies developed for military purposes eventually found civilian applications. Radar became weather forecasting, air traffic control, and the microwave oven. Nuclear reactors became the cleanest source of civilian power. ARPANET became the Internet that is now the foundation of

the modern economy. The military was the technological frontier, and the civilian economy was the beneficiary.[22]

Since roughly the 1990s, this relationship has been reversing. The most important technologies for contemporary military capability artificial intelligence, autonomous systems, advanced semiconductors, cybersecurity tools, and space launch capabilities are being developed primarily in the civilian sector, often by commercial firms, and are being spun off to military applications. The US military's increasing dependence on commercially available satellite imagery, AI-enabled logistics, and commercial cloud computing is not a temporary aberration. It is a structural shift in where the technological frontier now sits.

This spin-on reversal has profound implications for India. India's civilian technology sector, particularly in software, AI, and space, is genuinely world-class in ways that its defence sector is not. The question of how to build institutional bridges that allow India's civilian technological strengths to flow into defence applications is, arguably, the central practical challenge that this article illuminates. ISRO's demonstrated launch capability, the Indian software industry's AI and data engineering strengths, and the emerging deep-tech startup ecosystem are assets that a well-designed dual-use policy could leverage. India's current defence innovation system was earlier almost entirely blind to them, but now partially blind.

The dual-use question also opens onto export control regimes and the geopolitics of technology. The Wassenaar Arrangement, International Traffic in Arms Regulations (ITAR), and the emerging semiconductor export controls of the 2020s shape what India can import, what technology partners it can access, and what the cost of technological dependence is.[23] The decision to rely on Russian platforms and the consequences of that dependence for spare parts availability after 2022 are a case study in how export control regimes and geopolitical alignment interact with defence innovation choices.

Civilian-Led vs. State-Led Innovation: A Comparative Understanding

The debate between civilian-led and state-led innovation has calcified into one of the most unproductive binaries in technology policy. Market advocates point to the chronic inefficiency of state-owned enterprises, their bureaucratic inertia and their immunity to competitive discipline, and their tendency to optimise for institutional survival rather

than technological performance. Statists counter that markets systematically fail to price security externalities and that private capital will not bear the risks of frontier research at the necessary scale.[24] The most transformative technologies in history were built on public investment that no private firm would have voluntarily undertaken. Both positions contain genuine insights, but neither is sufficient. The binary framing itself is the primary obstacle to designing innovation systems that actually work.

The resolution lies in recognising that the relevant distinction is not between state and market ownership but between state and market risk-bearing capacity and that this capacity varies systematically and predictably across different stages of the innovation pipeline. Once this reframing is made, the policy question changes from the ideologically charged "state or market" to the analytically tractable "At which stage should which institution bear the risk, and why?". This is not a compromise between two positions. It is a more accurate description of how successful innovation systems have actually functioned, empirically, across the cases that matter most.

The argument begins with a structural fact about early-stage frontier research that markets cannot overcome through ingenuity or incentive design. The time horizons required, often measured in decades rather than years, exceed the planning horizons of any private firm operating under normal capital market conditions. The capital requirements are too large, the probability of any specific technical approach succeeding too uncertain, and the inability to appropriate the full social returns too profound for private investment to be adequate.[25] This is not a contingent feature of particular markets or particular technologies. It is a structural property of basic research and early-stage development at the technological frontier, identified by Arrow in 1962 and confirmed by every major empirical study of research investment since.[26] Mariana Mazzucato's contribution is to demonstrate, with granular historical evidence, that this is not merely a theoretical prediction but a documented reality. The internet, GPS, the semiconductor, touchscreen technology, and the algorithms underlying modern AI, each trace their lineage to patient, risk-tolerant state investment at precisely the stage where private capital had retreated or never arrived. DARPA's institutional architecture embeds this logic operationally, structuring its programme managers with a mandate to fund the genuinely speculative and to maintain portfolio diversity across competing technical approaches.

The picture inverts, however, at later stages of the innovation pipeline development, such as manufacturing and competitive procurement scale-up. State-owned enterprises and government laboratories operating without competitive pressure face what economists call the soft budget constraint.[27] The key compromises made in such ventures are poor performance being accommodated rather than penalised, cost overruns being absorbed rather than attributed, and schedule slippage being explained rather than terminated. This is not a failure of individual leadership or organisational culture, though it can manifest as both. Private firms do not innovate better than state enterprises at every stage. They execute better under competitive pressure at the stages where execution is what matters.

India's defence innovation system is a near-perfect illustration of what happens when this stage-differentiated logic is ignored in both directions simultaneously. DRDO, HAL, and the Ordnance Factory ecosystem have historically borne risk at every stage of the innovation pipeline from basic research through development, manufacturing, and in some cases operational support, including the later stages where their structural immunities to competitive discipline impose the highest costs.[28] The Tejas programme, which required over three decades and extraordinary expenditure to reach initial operational clearance, is less a story of technical failure than of institutional design failure. It is a procurement and development system that provides no mechanism to impose consequences on cost growth, requirements inflation, or schedule slippage.[29] Simultaneously, the system has failed to attract serious private sector engagement at early stages precisely because of the risk levels, time horizons, and capital requirements of frontier defence R&D.[30]

Policy Recommendations for an Integrated Innovation Approach

Innovation, on top of the above-discussed structural and systematic architecture within the different theoretical framework, should diffuse among the various organisations as a culture. The lack of a theoretical framework available to the defence sector is probably because the theorists and scholars of the domain thought of it as a phenomenon beyond sectoral constraints. Innovation, in an abstract sense, is synonyms with freedom, and freedom is the opposite of constraints. To inculcate a culture of innovation, the defence industrial base and the private sector must pool their joint capabilities within an integrated architecture supported by the immense financial

might of a nation. The policymakers must create a system where the barriers to innovation in the defence sector are complemented and addressed by the capabilities of the private sector and vice versa. To achieve that, the government of India should install a separate Ministry of Innovation (MoI) on the lines of its existing apex policy-making institution, like NITI Aayog. Such a ministry should be mandated to direct different ministries and departments of the government towards an innovation trajectory which aligns with the future vision and ambitions of India at 2047. A ministry of innovation functioning under the Prime Minister's Office (PMO) will be able to have a doctrinal kind of supervision over innovation happening with and without the government's support and hence will be able to enhance inter-ministerial coordination to create a whole-of-the-nation innovation pathway for innovators.

Conclusion

The framework this chapter constructs is not a synthesis that resolves the tensions between the four traditions. It is a composite lens that uses each tradition to illuminate what the others cannot see. Schumpeter tells us that the discontinuities matter as much as the increments and that the creative destruction of existing institutional arrangements is as important as the creation of new technology. The MIC/RAND tradition tells us that institutional capture and procurement pathology are not aberrations but the default equilibrium of any sustained state-defence-industry relationship. The RMA tradition tells us that technology without doctrine and organisation is irrelevant capability and that the hardest part of military innovation is not invention but adoption. The NIS tradition tells us that innovation cannot be mandated; it must be cultivated through institutional ecology that takes decades to build. Mazzucato adds the normative spine: the state need not be ashamed of its role as the primary risk-taker at the frontier. It suggests that a state must demand a return on that investment in the form of technological sovereignty, spillovers into the civilian economy, and institutional capacity that outlasts specific programmes.

The most important defence technologies of the next two decades will not be developed in DRDO laboratories. They will be developed in AI research labs, semiconductor fabs, and commercial space companies. Whether India can build the institutional bridges to convert civilian technological strength into military capability is the central question. India's defence innovation challenge is, at root, a problem of

institutional design under conditions of strategic urgency, and that is precisely what this theoretical architecture has been constructed to illuminate.

“Greatest gifts of wars are those who survived them and now know the value of peace and have the strength to preserve it at all cost.”

- *Author*

Declaration

I declare that this manuscript is being submitted exclusively to CENJOWS for publication consideration, is original, and has not been published or submitted elsewhere. I further certify that it contains no classified, restricted, or sensitive information and is based entirely on open-source material suitable for publication in the public domain.

ENDNOTES

[1] Reuven, Nir, and Eitan Shamir. "The Shift in Technological Dominance and the Adaption of Open Innovation by the Defence Sector." Defense & Security Analysis 41, no. 3 (2025): 392–415. https://doi.org/10.1080/14751798.2025.2484920.

[2] Pant, Vaibhav. "India Remains 2nd Largest Arms Buyer, Russia's Share in Imports Drops, France & Israel Gain—SIPRI." ThePrint, March 9, 2026. https://theprint.in/defence/india-remains-2nd-largest-arms-buyer-russias-share-in-imports-drops-france-israel-gain-sipri/2874000/.

[3] Wolf, Charles. Military-Industrial Complexities. 1969. https://www.rand.org/pubs/papers/P4177.html, Bartholomees, J. Boone, ed. US Army War College Guide to National Security Policy and Strategy. 1: Theory of War and Strategy. 3rd ed. With SSI. Strategic Studies Institute, 2008.

[4] Godin, Benoit. "National Innovation System: The System Approach in Historical Perspective." Science Technology & Human Values - SCI TECHNOL HUM VAL 34 (June 2009): 476–501. https://doi.org/10.1177/0162243908329187.

[5] Buderi, Robert. The Invention That Changed the World: How a Small Group of Radar Pioneers Won the Second World War and Launched a Technological Revolution. 1. Touchstone ed. Sloan Technology Series. Simon & Schuster, 1997.

[6] Peralta, René. "Alan Turing's Everlasting Contributions to Computing, AI and Cryptography." NIST, June 23, 2022. https://www.nist.gov/blogs/taking-measure/alan-turings-everlasting-contributions-computing-ai-and-cryptography.

[7] Lambertini, Luca. "A Schumpeterian View of the Interplay between Innovation and Concentration in the EU Defence Industry." Defence Studies 23, no. 4 (2023): 608–25. https://doi.org/10.1080/14702436.2023.2277474.

[8] Lambertini, Luca. "A Schumpeterian View of the Interplay between Innovation and Concentration in the EU Defence Industry." Defence Studies 23, no. 4 (2023): 608–25. https://doi.org/10.1080/14702436.2023.2277474.

[9] Kriger, Boris (Bruce). "The Wars of the Worlds and the Politics of Destruction." Medium, April 9, 2026. https://medium.com/@krigerbruce/the-wars-of-the-worlds-and-the-politics-of-destruction-0d8d94509768.

[10] Petropoulos, Fotios, Gilbert Laporte, Emel Aktas, et al. "Operational Research: Methods and Applications." Journal of the Operational Research Society 75, no. 3 (2024): 423–617. https://doi.org/10.1080/01605682.2023.2253852.

[11] Behera, Laxman Kumar. "Examining India's Defence Innovation Performance." Journal of Strategic Studies 44, no. 6 (2021): 830–53. https://doi.org/10.1080/01402390.2021.1993829.

[12] Walker, Derek H. T., and Stephen M. Rowlinson, eds. Procurement Systems: A Cross-Industry Project Management Perspective. Taylor & Francis, 2008.

[13] Mazzucato, Mariana. "The Entrepreneurial State." Soundings 49, no. 49 (2011): 131–42. https://doi.org/10.3898/136266211798411183.

[14] Mazzucato, Mariana. "Mission-Oriented Innovation Policies: Challenges and Opportunities." Industrial and Corporate Change 27 (October 2018): 803–15. https://doi.org/10.1093/icc/dty034.

[15] Mazzucato, Mariana. "The Entrepreneurial State." Soundings 49, no. 49 (2011): 131–42. https://doi.org/10.3898/136266211798411183.

[16] Mazzucato, Mariana. "Mission-Oriented Innovation Policies: Challenges and Opportunities." Industrial and Corporate Change 27 (October 2018): 803–15. https://doi.org/10.1093/icc/dty034.

[17] Kattel, Rainer, and Mariana Mazzucato. "Mission-Oriented Innovation Policy and Dynamic Capabilities in the Public Sector." Industrial and Corporate Change 27, no. 5 (2018): 787–801. https://doi.org/10.1093/icc/dty032.

[18] Sikka, Anushka, and Smit Shah. "Reimagining India's Defence Innovation Pipeline Through Design Leadership - Drone Federation India News." Government of India. Drone Federation

India (DFI), January 2, 2026. https://www.dronefederation.in/media-hub/reimagining-indias-defence-innovation-pipeline-through-design-leadership.

[19] Behera, Laxman Kumar. "Examining India's Defence Innovation Performance." Journal of Strategic Studies 44, no. 6 (2021): 830–53. https://doi.org/10.1080/01402390.2021.1993829.

[20] Weiss, Linda, ed. America Inc.? Innovation and Enterprise in the National Security State. Cornell Studies in Political Economy. Cornell University Press, 2014.

[21] Cowshish, Amit. "Challenges in Reforms of DRDO." Think Tank. Vivekanand International Foundation, VIF, October 5, 2023. https://www.vifindia.org/print/12037.

[22] Aebi, Tobias, Alexey Pankov, Artem Malkov, and Adnan Merhaba. "Unlocking the Strategic Power of Dual-Use Technologies | Arthur D. Little." Think Tank. ArthurDLittle, October 10, 2025. https://www.adlittle.com/en/insights/viewpoints/unlocking-strategic-power-dual-use-technologies.

[23] Yadav, Cdr Gourav. "India's Semiconductor Push: Defence Implications." Think Tank. MP-IDSA, November 20, 2025. https://idsa.in/publisher/issuebrief/indias-semiconductor-push-defence-implications.

[24] Mahmoud, Ahmed Ragab. Why Markets Fail: Externalities, Information Gaps, and Policy Solutions. 2025. https://doi.org/10.13140/RG.2.2.22550.41287.

[25] Gansler, Jacques S. Democracy's Arsenal: Creating a Twenty-First-Century Defense Industry. MIT Press, 2011.

[26] Arrow, Kenneth. "(1962),The Economic Implications of Learning by Doing', Review of Economic Studies, XXIX (3), June, 155-73 | Request PDF." Researchgate. ResearchGate. Accessed May 20, 2026. https://www.researchgate.net/publication/299290053_1962The_Economic_Implications_of_Learning_by_Doing'_Review_of_Economic_Studies_XXIX_3_June_155-73.

[27] Kornai*, János. "The Soft Budget Constraint." Kyklos 39, no. 1 (1986): 3–30. https://doi.org/10.1111/j.1467-6435.1986.tb01252.x.

[28] Sikka, Anushka, and Smit Shah. "Reimagining India's Defence Innovation Pipeline Through Design Leadership - Drone Federation India News." Government of India. Drone Federation India (DFI), January 2, 2026. https://www.dronefederation.in/media-hub/reimagining-indias-defence-innovation-pipeline-through-design-leadership.

[29] Behera, Laxman Kumar. "Examining India's Defence Innovation Performance." Journal of Strategic Studies 44, no. 6 (2021): 830–53. https://doi.org/10.1080/01402390.2021.1993829.

[30] Sikka, Anushka, and Smit Shah. "Reimagining India's Defence Innovation Pipeline Through Design Leadership - Drone Federation India News." Government of India. Drone Federation India (DFI), January 2, 2026. https://www.dronefederation.in/media-hub/reimagining-indias-defence-innovation-pipeline-through-design-leadership.