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MANAGEMENT OF DEFENCE TECHNOLOGIES

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MANAGEMENT OF DEFENCE TECHNOLOGIES

CONTENTS

PREFACE

Technology now decisively shapes the character and conduct of warfare. Precision strikes, networked battlefields, and new domains such as cyber and space make military effectiveness depend on a nation's ability to use, integrate, and maintain technology. For India, achieving strategic autonomy is critical in an increasingly uncertain and contested security environment.

This paper examines how managing defence technologies, especially through value chain development, contributes to the development of long-term capabilities. While much attention is paid to acquiring advanced platforms and systems, less focus is given to the key processes and structures necessary for developing, absorbing, and sustaining technology. This work addresses the gap between system acquisition and the broader capability development process.

The study examines how military technology evolves, how the global defence industry transforms, and how technological innovation occurs. It specifically analyses how these developments manifest in India, where policy, bureaucracy, industry, and the armed forces interact in complex ways. The analysis contends that India must move beyond a fragmented and procurement-focused approach. Instead, it advocates for an integrated framework that treats technology as part of a broader ecosystem, facilitating cohesive progress across all stakeholders.

The concept of value chains offers a useful analytical lens by highlighting the importance of aligning it at every stage, from research and development to production, integration, and lifecycle support, to achieve operational effectiveness. The book's key argument is that this alignment is essential for indigenisation and self-reliance efforts to be successful and yield the intended outcomes. This work is primarily based on open-source material and adopts a qualitative and descriptive approach. Rather than offering definitive solutions, it aims to provoke thought and contribute to ongoing discourse on defence reforms and capability development. Due to the complexity and sensitivity of the subject, there are inherent limitations, especially regarding access to classified information and programme-specific details.

The views expressed in this book are personal and do not necessarily reflect those of any organisation or institution. The intent is to present an objective analysis that may be of value to practitioners, policymakers, researchers and students of military affairs.

The author thanks his seniors, colleagues, and mentors for their guidance and encouragement. Any shortcomings are entirely the author's own.

Major General Rajat Kumar

EXECUTIVE SUMMARY

Technology and Strategic Autonomy. Technology now decisively shapes the character and conduct of warfare. For India, the pursuit of strategic autonomy in an increasingly contested security environment makes the effective management of defence technologies a matter of national priority. This study examines how managing defence technologies, particularly through value chain development, contributes to building long-term military capability.

Scope and Approach. The work adopts a qualitative, descriptive approach based primarily on open-source material. It analyses how military technology evolves, how the global defence industry has transformed, and how technological innovation occurs, with specific application to India's policy, institutional, and industrial environment.

Key Arguments. India must move beyond a fragmented, procurement-centric approach and embrace an integrated framework treating technology as part of a broader ecosystem. The concept of value chains, aligning research and development, production, integration, and lifecycle support, is central to successful indigenisation.

Findings. Structural inefficiencies, a bureaucratic mindset, limited civil-military integration, and dependence on external sources continue to constrain India's defence technology ecosystem. The Military-Industrial Complex (MIC) remains underdeveloped, and initiatives such as Positive Indigenisation Lists represent symptoms-focused remedies rather than systemic solutions.

Recommendations. The study proposes a policy framework encompassing procurement policy reform, reduction in acquisition categories, adoption of Detailed Project Reports for every acquisition programme, decentralised tactical innovation, collaborative priority innovation with global partners, and structured investment in Professional Military Education in technology management.

CHAPTER 1

INTRODUCTION

> "Our aim is to boost defence production, develop new technology and give significant roles to private players in the defence sector"

Narendra Modi,
Hon'ble Prime Minister

Background

Technology and warfare share a symbiotic relationship. This became evident to the world on 16 January 1991 when the American-led coalition commenced an air campaign against Iraq. The technology gap between the two sides made the air campaign a one-sided contest. The ground operations, commencing on 24 February 1991, reconfirmed the implications of superior military technology: the coalition ground forces decimated what remained of the Iraqi forces and liberated Kuwait in approximately 100 hours of combat.

There is adequate evidence to suggest that even the US defence establishment had not anticipated this outcome. Renowned American military experts had anticipated some 10,000 casualties in ten days of combat. Interestingly, Indian defence experts disagreed and predicted an easy coalition victory.[1] The seeds of victory in the land battle were partially sown by General Creighton Abrams, who identified five must-have new weapons during his tenure as Chief of Staff of the US Army from 1972 until his untimely death in 1974: the M-1 Abrams tank, the M2/M3 Bradley Infantry Combat Vehicle, the AH-64 Apache attack helicopter, the UH-60 Black Hawk utility helicopter, and the Patriot air defence missile.[2]

Despite conceiving, nurturing, and exploiting battle-winning technologies, the US military failed to appreciate that a major revolution in warfare was underway. Experts like Andrew Marshall opined that the changes witnessed were just the beginning and the full nature of the changes in the character of war was yet to emerge.[3] The term "Revolution in Military Affairs" was examined and found to have been first introduced by Michael Roberts in a 1955 lecture, explaining it from a historical rather than a futuristic perspective. The term "revolution" in the context of technology today seeks to describe its impact in steering discontinuity in the character of war.

Context and Rationale

The character of warfare has evolved in tandem with technological advancement. From the industrial age to the contemporary era marked by digitisation, artificial intelligence, and networked systems, technology has consistently shaped how military power is generated, sustained, and applied. Increasing battlefield transparency, accelerated decision cycles, and the convergence of multiple domains have further elevated technology's role as a decisive enabler of military effectiveness.

In the contemporary strategic environment, technology is no longer confined to the battlefield alone. It has emerged as a critical instrument of national power, influencing economic strength, geopolitical positioning, and strategic autonomy. Concepts such as the Revolution in Military Affairs (RMA), the Military-Industrial Complex (MIC), and Military Civil Fusion (MCF) reflect this expanded scope.

Indian Context

For India, the pursuit of technological capability assumes added significance in light of its aspiration to achieve strategic autonomy. Despite possessing a strong scientific base and an expanding industrial ecosystem, the Indian defence sector continues to face challenges in translating technological potential into operational capability. Structural inefficiencies, fragmented institutional frameworks, limited integration between civil and military domains, and dependence on external sources for critical technologies continue to constrain progress.

The challenge, therefore, is not merely one of acquiring advanced technologies, but of managing them effectively across the entire value chain, encompassing research and development, production, integration, and sustainment. This calls for a shift from a platform-centric approach to a systems-oriented perspective that integrates the efforts of the armed forces, industry, academia, and the state.

Chapter Overview

The study is structured to progressively build an understanding of the subject. It begins with a diagnostic analysis of military technology (Chapter 2), followed by an examination of the evolution of the defence industry in the post-World War II period (Chapter 3). Subsequent chapters analyse the classification and absorption of technologies (Chapter 4), assess the Indian context (Chapter 5), and finally propose a way ahead for technology infusion in the armed forces (Chapter 6).

Management of defence technologies, anchored in robust value chains, will play a critical role in enabling strategic autonomy. Achieving this objective will require coordinated efforts across government, the military, and industry, supported by an enabling policy environment and a forward-looking approach to technological innovation.

CHAPTER 2

MILITARY TECHNOLOGY: A DIAGNOSTIC ANALYSIS

"Any sufficiently advanced technology is indistinguishable from magic"

Arthur C. Clarke

Contextualising Military Technology

Military technology is described as a range of weapons, equipment, structures, and vehicles used specifically for the purpose of warfare, encompassing the knowledge required to construct such technology, to employ it in combat, and to repair and replenish it.[4] For the purpose of this paper, military technology is the innovative use of scientific knowledge to develop technology-based solutions to solve problems on the battlefield. It explicitly omits the use of technology for day-to-day administrative functions.

Military Revolution, Innovation, Adaptation, and Emulation

Revolution as a term implies that change is profound rather than rapid, that new methods of warfare are more powerful than older ones.[5] Revolution in Military Affairs (RMA) reflects a discontinuity in trends of change. While no RMA is possible without technology, it is not limited to technology alone. Besides weapons and equipment, RMA also involves new structures, organisations, operating concepts (doctrine), training, and logistics methods. Given the nature and scope of change ushered in by RMA, it is usually attempted during peacetime. Some authors and theorists also use the term "innovation" to describe major military change.[6] Therefore, revolution and innovation convey the similar kind of meaning in certain contexts and are usually undertaken during peace.

Innovation and RMA undertaken during peacetime are deliberately thought through and war-gamed but can never be fully tested in warlike conditions. Under battle conditions, peacetime innovation may therefore necessitate changes. Adaptation, as relevant to the military, therefore refers to adjustment to existing methods or ways of execution to suit environmental realities during conflict. Multiple adjustments over a period of time that result in the evolution of new methods also qualify as military adaptation.

Emulation involves introducing new methods or ways of force application by replicating other military organisations.[7] Usually, successful practices employed by effective militaries are emulated by those seeking to catch up. Often, ideas and practices are suitably modified before they are adopted. For instance, in India, the Reorganised Army Plains Division (RAPID) is a suitably modified emulation of the American Reorganisation Objective Army Division (ROAD).[8]

From the above, it emerges that technological change can take many forms: innovation (i.e., RMA), adaptation, and emulation. Historical evidence suggests, however, that it is not just technological sophistication which matters but a larger framework. During World War II, the French had better tanks than the Germans, while the Germans had better radars than the British, yet in both cases the side with technologically superior equipment fared poorly. In the Indian context, the Pakistan Army, equipped with American M-48 Patton Tanks and F-86F Sabre jets, emerged second-best against Indian tanks and aircraft.

Military Effectiveness

The role of the armed forces is to deter war and, should deterrence fail, to achieve victory. The ability of the armed forces to secure victory therefore emerges as the benchmark of military effectiveness.

In a RAND report, Ashley Tellis suggested that military effectiveness is the conversion of resources provided to the military into effective warfighting capability.[9] In a study funded by the US Office of Net Assessment in the 1980s, Allan R. Millett and Williamson Murray contended that military effectiveness is the process by which armed forces convert resources to derive maximum combat power.[10] Neither provides any reference to victory as the desired end state. A comprehensive definition is therefore offered:

"Military effectiveness is the process by which a nation exploits political guidance, structures for civil-military relations, organisation, equipment, training, concepts (doctrine), and capacity for innovation (as ways), to convert resources in terms of funds, manpower, technology, and natural resources (as means), to achieve victory (the end state)."

Technology and Military Effectiveness

Technology and warfare share a symbiotic relationship. In the eighteenth century during the Age of Enlightenment,[11] that systematic study of warfare emerged as universal laws and principles could be taught and applied almost universally with a few adaptations. It was during this period that engineers developed field fortifications, ballisticians calculated the trajectory of artillery weapons, and administrators planned the logistical requirements of moving men and material. It was also during this period that thinkers like Carl von Clausewitz used scientific terms such as friction, mass, centre of gravity, and culmination point as metaphors to develop military theories.

The next significant change emerged with the invention of the internal combustion engine which was commercialised in 1866 and electronics (the invention of the diode in the early 1900s). While industrialisation enabled the equipping of mass armies of the industrial age, the internal combustion engine overcame conventional limitations of human and animal endurance on the battlefield. For instance, in 1918, a foot soldier could only manage six km per hour in assault and 25 km per day in an unopposed forced march. By 1940, the German Panzerkampfwagen III Ausführung E (PzKpfw III E) tank could make 40 km per hour on roads and 18 Km per hour cross country.[12] It is, therefore, not surprising that the tank powered by an internal combustion engine eventually replaced the horse in Cavalry units. Electronics made it possible to develop communication and radar technologies which had reached early maturity during the inter-war period between the two world wars. During the early stages of World War 2, the integration of Combat Net Radios (CNR) with tanks enabled the Germans to gain an asymmetric advantage over their adversaries in command-and-control functions. On the other hand, the British used radar networks to provide early warning of German incoming air raids across the English Channel. Similarly, while all the navies used sonar on ships and submarines, analytical fields like Operational Research and devices like Turing Machines were developed to aid and assist the military mind in decision-making. These advances led to the development of Platform-Centric Warfare.

Fusion of electronics and software and their incorporation in platforms/ weapons and munitions hold the key to future trends. Incorporation of electronics and software based new technologies in old platforms continue to deliver exponentially improved performance (combat effectiveness), reduced maintenance and breakdown, lower running cost, ease of training etc (efficiency). For instance, the B-52 bomber aircraft, inducted into the US Air Force in 1955 has received significant upgrades with new engines, weapons and avionics still continues to be in service. Electronics (computers) mated with data and suitable algorithms (Artificial Intelligence or AI) also hold the key to faster and more accurate inputs for decision making.

Military effectiveness at the technological level can be defined as the ability of the country to adequately equip the military with desired technologies to achieve victory. It emerges that the ultimate objective of military technologies should be to provide an asymmetric advantage on the battlefield. The focus should be to exploit technology to (1) solve problems faced by soldiers on the battlefield in achieving their missions and (2) gain an asymmetric advantage over the adversary by being ahead in the technology curve. In terms of significance, the former should be accorded greater priority over the latter. These technologies would be a mix of imported (emulation), produced jointly through joint ventures in the host nation and/or produced by private and government owned entities.

CHAPTER 3

EVOLUTION OF DEFENCE INDUSTRY POST WORLD WAR II

"You may not be interested in war, but war is interested in you."

- Leon Trotsky

Industrial Revolutions

Experts opine that the world has so far witnessed three distinct industrial revolutions.[13] The first revolution was powered by steam and resulted in large factories capable of high-volume production and the development of railroads. The second industrial revolution was led by the Internal Combustion Engine (ICE) and electronics, resulting in advancements in transportation, communications, and detection capabilities. The third industrial revolution, often called the digital revolution, began in the 1950s with the invention of the transistor and integrated circuitry.[14]

In 2016, Klaus Schwab authored The Fourth Industrial Revolution (4IR), arguing that powered by new technologies, the physical, digital, and biological spheres will increasingly converge. Experts like Andrew Krepinevich opine that while precision warfare continues to mature, a new military revolution is taking shape, enabled by commercial technologies including Artificial Intelligence (AI), additive ("3D") manufacturing, synthetic biology, and quantum computing, along with military-driven technologies like directed energy and hypersonic weapons.[15]

Rise of the Military-Industrial Complex (MIC)

Yoram Evron and Richard Bitzinger[16] have highlighted that it was only in the latter half of the nineteenth century and early twentieth century that select private firms began specialising in the manufacture of military equipment. After World War II, commercial industries were strained to keep pace with demands for technological innovation as well as the required scale of production.[17] These developments led to the creation of a permanent, stand-alone MIC.

India was not oblivious to these changes. The Indian Government undertook consolidation of the private defence industry and funded non-private establishments to meet the requirements of the armed forces. Hindustan Aircraft Limited, established in 1940[18] as a private venture, was nationalised by the British in 1942. Mazagon Dock Shipbuilders (established 1934) and Garden Reach Shipbuilders & Engineers Ltd (GRSE, established 1884) were nationalised in 1960. The Indian government also established Bharat Electronics Limited (BEL) in 1954, the Heavy Vehicles Factory (HVF) in 1961, and the Vehicle Factory Jabalpur in 1954.

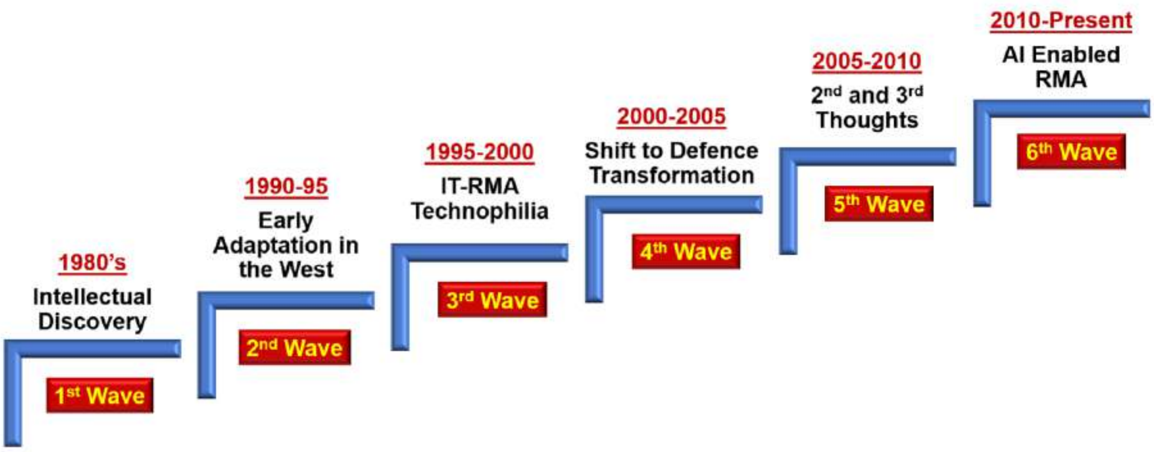

Figure 1. The Six RMA Waves [19]

Discovery of RMA

The trigger for the RMA debate was the Gulf War of 1991. The debate in the US was initiated in 1993 by Andrew Marshall, the Director of Net Assessment, who opined that the US military was at the beginning of a military revolution and that the full nature of the changes in the character of war was yet to emerge.[20] He prophesied that long-range precision strikes and information warfare were the two dominant ideas about how warfare may change. Michael Raska reasons that in 2006, Colin Gray suggested five stages or "RMA Waves" and proposes the need to add a sixth wave.[21] Additional issues highlighted by Michael Raska[22] are as follows:

- The "Five Waves" identified by Colin Gray are a sub-set of one comprehensive "Information Technologies RMA" or IT-RMA.

- Despite profound technological advancements and exploitation of RMA technologies, the RMA trends have not yet realised their envisaged expectations.
- Even as the emerging AI-RMA reflects a discontinuity from past trends, its dimensions are far from certain.

Change in Contextual Setting

For the US and the West, the end of the Cold War and the spectacular victory over Iraq in 1991 changed the contextual setting and produced two significant assumptions. First, there was no existential threat to the liberal world order. Second, the significant asymmetry in military capabilities enjoyed by the US and its allies could easily overcome any military threat. This belief was also advocated by political scientists like Francis Fukuyama in The End of History and the Last Man (1992).

These assumptions led to the re-emergence of the enduring "guns versus butter" debate. In 1990, the United States spent approximately 5.2 per cent of its GDP on defence,[23] with defence research and development (R&D) accounting for about 0.7 per cent.[24] By 1991, US defence expenditure had declined to about 4.9 per cent of GDP, while defence Research, Development, Test and Evaluation (RDT&E) spending stood at approximately 0.55-0.60 per cent of GDP. Although overall defence spending rose during the Global War on Terror, RDT&E expenditure, the Department of Defense's Research, Development, Test and Evaluation appropriation, a broader budget category than the narrower "R&D" definition used in some comparative studies , generally remained within the 0.40–0.55 per cent of GDP range. Contrary to a commonly cited decline narrative, which reflects that narrower R&D-outlay measure (approximately 0.29 per cent of GDP in 2017, per the US Congressional Research Service), DoD's RDT&E appropriation did not fall to 0.2 per cent of GDP; on the broader RDT&E measure, it remained around 0.45 per cent of GDP in 2018.[25] Increased emphasis on strategic competition with China and Russia after 2022 sustained this trend, with US defence RDT&E expenditure reaching approximately 0.48 per cent of GDP by 2025.[26]

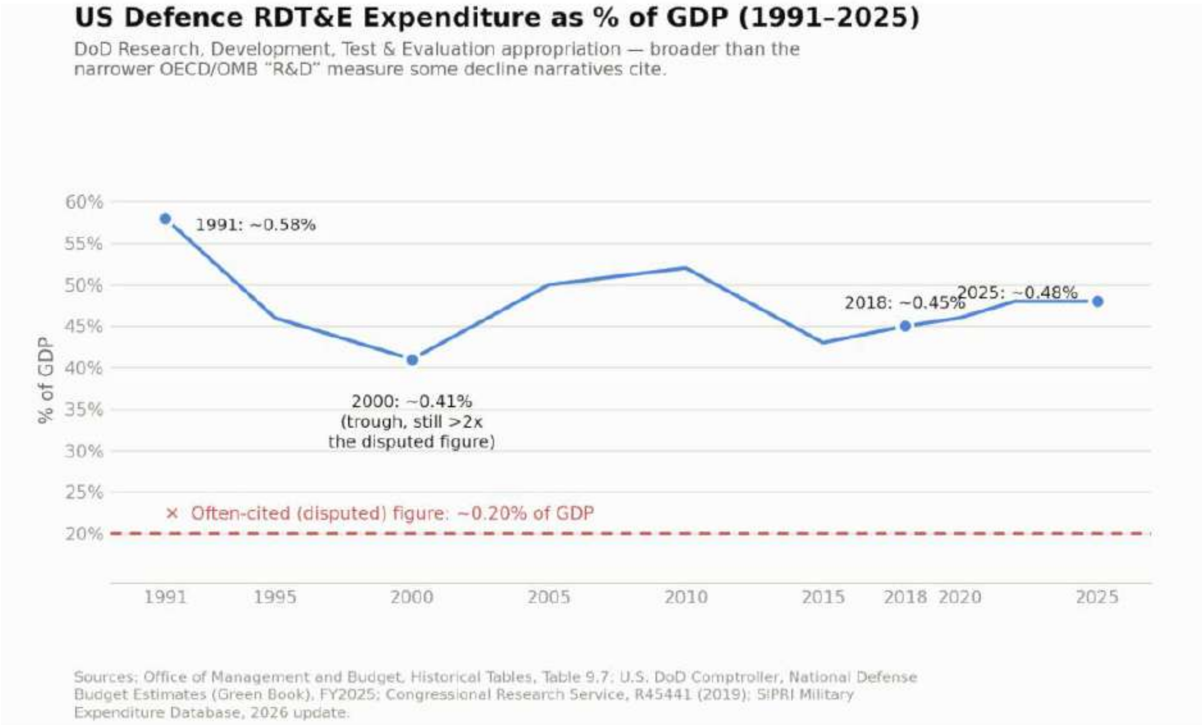

Figure 2: US Defence RDT&E Expenditure as Percentage of GDP (1990-2025)[27]

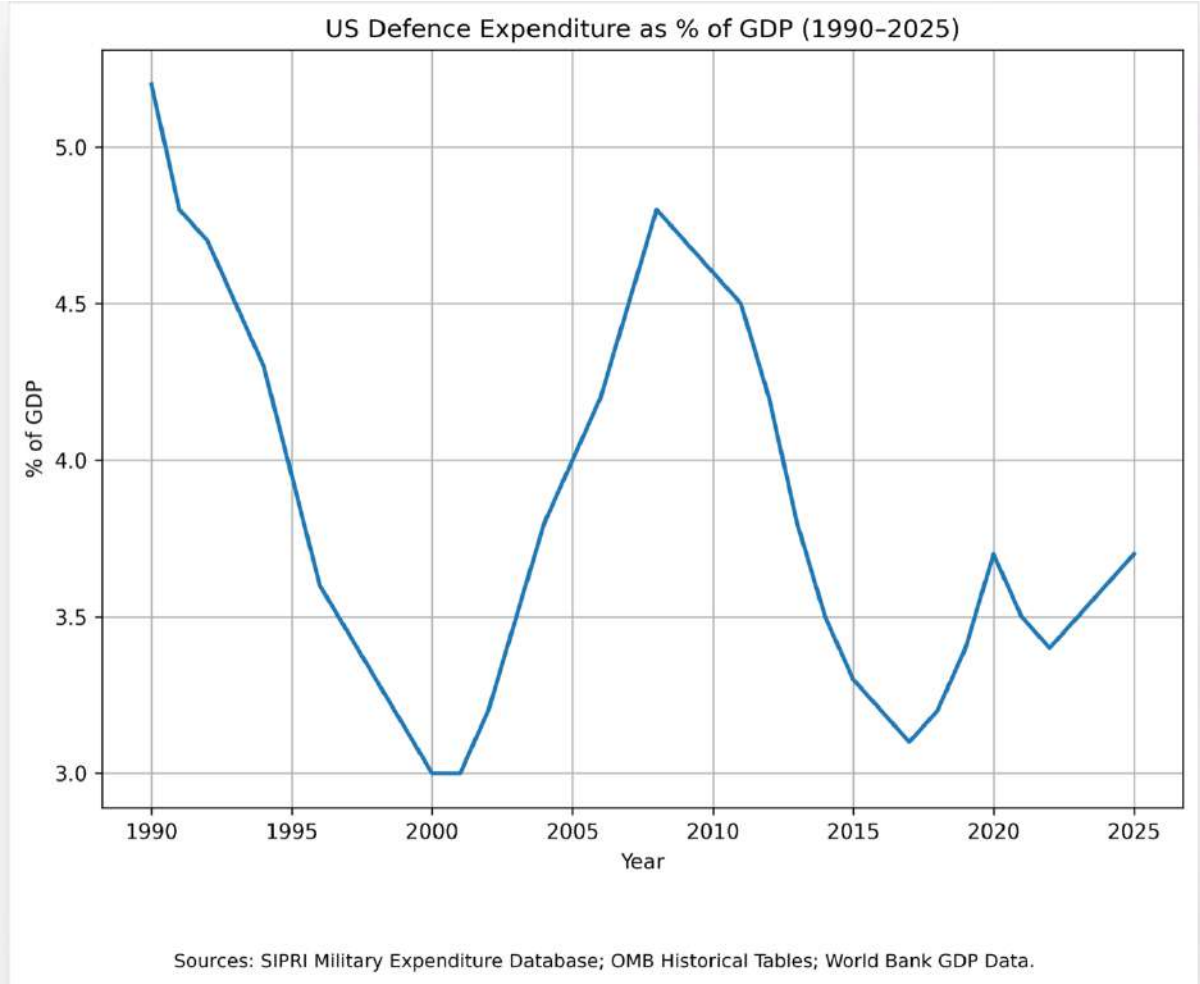

Figure 3: US Defence Expenditure as Percentage of GDP (1990-2025)[28]

The US defence expenditure declined sharply following the end of the Cold War, falling from approximately 5.2 per cent of GDP in 1990 to around 3.0 per cent by 2000. The Global War on Terror (GWOT) reversed this trend, with defence spending peaking at nearly 4.8 per cent of GDP in 2008. Subsequent drawdowns in Iraq and Afghanistan, together with budgetary constraints, reduced defence expenditure to around 3.1 per cent by 2017. Since 2020, renewed great-power competition and heightened geopolitical tensions have sustained defence spending at about 3.4-3.7 per cent of GDP, with expenditure projected at approximately 3.7 per cent in 2025.[29] A similar trend was observed across major European economies. Consequently, it became both rational and necessary for the military-industrial complex (MIC) to increasingly leverage the broader private-sector innovation and R&D ecosystem.

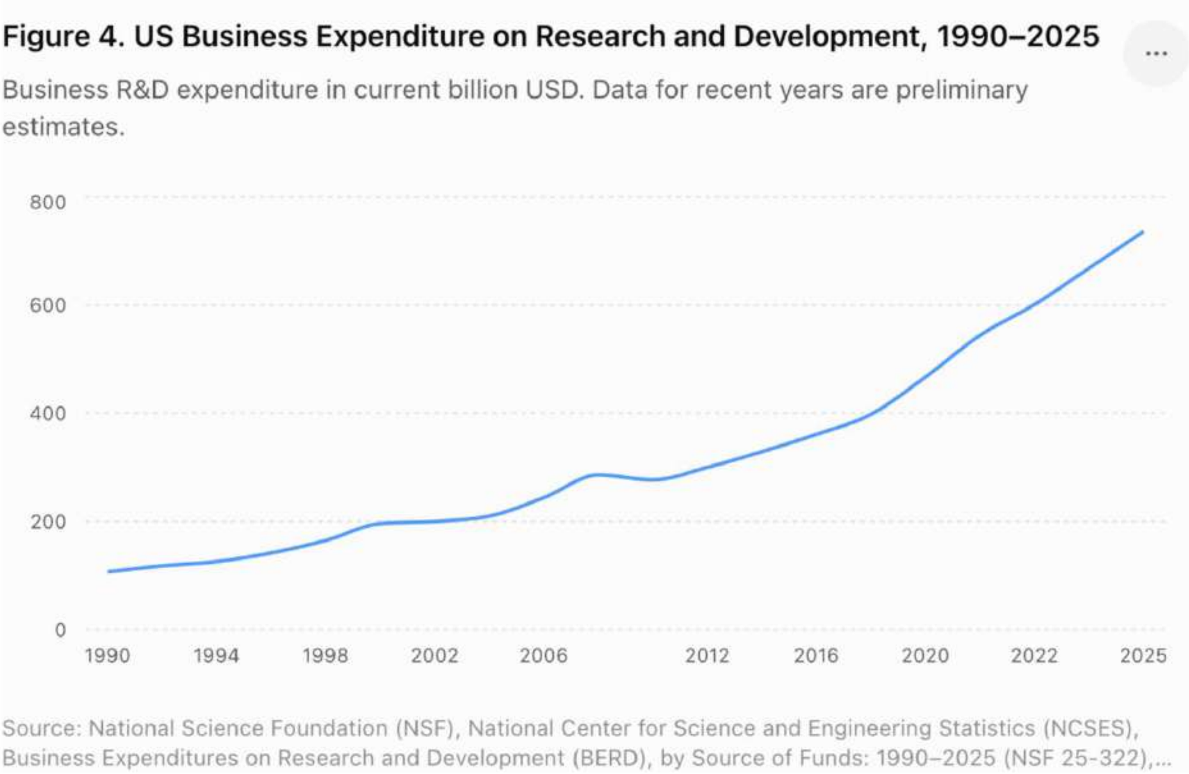

Figure 4. US Business Expenditure on Research and Development, 1990-2025 (Billion USD) [30]

Military-Civil Fusion (MCF)

The term Military Civil Fusion (MCF) was reported to be first used in 2007 by Hu Jintao, the General Secretary of the Chinese Communist Party.[31] However, it was in 2015 that Xi Jinping explained MCF as the "aligning of civil and defence technology development" and made it a national priority.[32] In practice, this concept involves tapping into the R&D facilities and progress made by private business and utilising dual-use technologies for military purposes. MCF does not deny the significance of MIC; rather, it conveys that increasingly, technologies will be dual-purpose and obtained from sources outside the traditional military-industrial base.

CHAPTER 4

CLASSIFICATION AND FORMS OF ABSORPTION OF MILITARY TECHNOLOGY BY THE ARMED FORCES

"Timely infusion of technology in the defence sector is crucial."

Rajnath Singh

The preceding chapters have established the symbiotic relationship between technology and warfare and traced the evolution of the global defence industry from the post-World War II era to the present. Having examined the macro-level forces shaping the Military-Industrial Complex and the emergence of Military-Civil Fusion, it is now necessary to look inward at how military technology is actually categorised and absorbed by armed forces. This chapter undertakes that diagnostic task, first by mapping the dominant trends in military technology and the pitfalls that accompany them, and then by offering a structured framework for classifying types of military technology and the corresponding forms of innovation through which they are inducted into service.

Technology Trends and the Technology Trap

The quest to understand technology will be incomplete without appreciating the trends in military technology. These could be identified as follows:

- Since the Bronze Age, an increase in lethality has been a constant feature, complemented by an increase in range since the Gunpowder Age. Traditional trends that form part of every era of warfare are therefore increased lethality and range.

- A major feature of warfare in the Industrial Era was the advent of the Internal Combustion Engine (ICE) and electronics on the battlefield. The ICE mitigated the limitations of human and animal endurance. Electronics facilitated the growing trend of improved detection and delivery of firepower. Fusion of electronics and software holds the key to future trends, AI and advanced algorithms enable faster and more accurate decision making.

- Besides the above, common trends suggest that old technologies constantly advance and mature, yielding improved combat effectiveness through greater lethality and equipment reliability, as well as greater efficiency through reduced maintenance, lower running costs, and ease of training.

Since the emergence of RMA, weapons built on potentially transformative technologies have been given names like "Assassin's Mace," "Silver Bullet," and "Wonder Weapons." However, the frequency of transformative technologies maturing is rather low. Even though super-technologies are theoretically feasible and offer tremendous potential, they are yet to mature to a stage wherein they can be tactically employed on the battlefield. For instance, the Rail Gun and the Electro-Magnetic (EM) Gun have been under development for decades.

Increasingly, the armed forces are falling into what could be referred to as the "Technology Trap". Common reasons why technology consistently disappoints despite its potential are as follows:

- Too many technologies, with military analysts suggesting "We have the technology, now let us find a problem to solve." This results in force-fitting technologies to solve lower-priority problems.

- Several attractive technologies have been at the edge of achieving a breakthrough for far too long. For instance, "Unimate," the first digitally operated programmable robot, was invented in 1954. For robotics to succeed in land warfare, the key requirement would be the capacity to make terrain irrelevant.

- Most emerging technologies have a narrow focus, implying restricted application with high costs of procurement and maintenance.

Absorption of Military Technology

Considering the likely impact of technology on warfare and the challenges involved in incorporating technologies in military equipment, adopting a granular approach is essential. Technology cannot be treated as a monolithic construct readily available for incorporation in military equipment. Induction of technologies also calls for changes in doctrine, military structures, training, and Professional Military Education (PME).

A unidimensional criterion based on envisaged standalone competitive advantage on the battlefield offers a viable basis for classifying types of military technologies:

- **Disruptive Technologies.** The term "Disruptive Innovation" was coined by Professor Clayton Christensen of Harvard University[33] to describe a process by which a product or service takes root initially in simple applications and then relentlessly moves upmarket. Similarly, "Disruptive Technologies" could be understood as frugal and simple technologies applied to a problem in such a way that the symmetry of military force between competitors fundamentally changes.[34] Drones and loiter munitions are suitable examples.

- **Cutting Edge Technologies.** "Cutting-Edge Technologies" refer to technological devices, techniques, or achievements that employ the most current and high-level developments, technology at the frontiers of knowledge.[35] Javelin and Spike Anti-tank Guided Missiles, featuring advanced sensor and guidance technologies with high hit probabilities and top-attack capability, are apt examples.

- **Niche Technologies.** In the military context, "Niche Technologies" refer to high-technology equipment and platforms available to only a few armed forces, for example, stealth aircraft, nuclear submarines, and ballistic missile defence systems.

- **Breakthrough Technologies.** A "Breakthrough Technology" introduces a radically new capability or a performance improvement of at least an order of magnitude.[36] Examples include the invention of aircraft, the Global Positioning System (GPS), and the DARPA-funded Brain-to-Machine Interface project.[37] It is important to appreciate that Cutting-Edge and Breakthrough technologies evolve and mature over long periods, often up to fifteen years or more.

Technology Readiness Levels and Manufacturing Readiness Levels

Technology Readiness Level (TRL), designed by NASA in the 1970s, establishes the maturity of technologies on a scale of 1 to 9, with 9 representing the highest level of mature technology.[38] Manufacturing Readiness Level (MRL), adopted in the US in 2005 and developed jointly by the US Department of Defence and industry working groups, quantitatively measures the maturity of a specified technology, component, or system from a manufacturer's perspective. MRLs are graded on a scale of 1 to 10.[39]

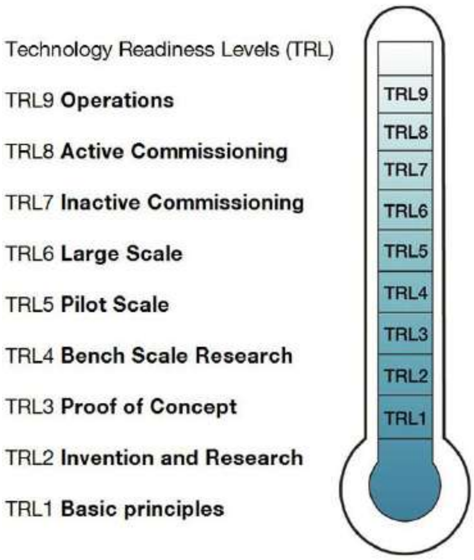

Figure 5. Technology Readiness Levels (TRLs)[40]

Phases	MRL	Definition
Operations and Support	10	Full Rate Production demonstrated and lean production practices in place.
Production and Deployment	9	Low Rate Production demonstrated. Capability in place to begin Full Rate Production.
Engineering and Manufacturing Development	8	Pilot line capability demonstrated. Ready to begin low rate production.
	7	Capability to produce systems, subsystems or components in a production representative environment.
Technology Development	6	Capability to produce a prototype system or subsystem in a production relevant environment.
	5	Capability to produce prototype components in a production relevant environment.
Material Solutions Analysis	4	Capability to produce the technology in a laboratory environment.
	3	Manufacturing proof of concept developed
	2	Manufacturing concepts identified
	1	Basic manufacturing implications identified

Figure 6. Manufacturing Readiness Levels (MRLs)[41]

Forms of Military Innovation

Technology has to be used innovatively to develop equipment, platforms, and munitions to enhance military effectiveness. Essential features of each type of technological innovation are as follows:

- **Tactical Innovation.** "Tactical Innovation" is a bottom-up process, initiated by troops on the ground to address a local problem by exploiting Commercial off-the-Shelf (COTS) equipment and Adaptive Technologies.[42] It produces timely solutions with little investment; results obtained are usually overhyped despite limited scope; it does not necessitate structural or doctrinal change; and it has effectiveness at its core through frugal means, while efficiency is a secondary outcome. The use of water pumps by Egypt to breach the bund on the Israeli side of the Suez Canal, and the use of hobbyist quad-copters for surveillance, are examples.

- **Incremental Innovation.** "Incremental Innovation" represents sustained or marginal improvement in a given technology driven by advancements in the industry. This type of innovation features continuity and, hence, presents negligible risk and low uncertainty. It is usually driven by the Original Equipment Manufacturer (OEM), represents marginal improvements through upgrades, and offers ease of operation, less training, simpler maintenance, and reduced cost. Installing Thermal Imaging Fire Control Systems (TIFCS) in T-72 Tanks and the introduction of Artillery Combat Command and Control Systems (ACCCS) are examples. The focus is on achieving efficiency relative to effectiveness.

- **Priority Innovation.** "Priority Innovation" represents an attempt to address mission capability gaps through the induction of major platforms and weapons systems and hence produces linear outcomes. It usually features cutting-edge technologies such as the S-400 Anti Ballistic Missile system and fully evolved Disruptive Technologies like armed drones. Changes require significant financial outgo over a long period of time. The primary focus is mission effectiveness, while efficiency is secondary.

- **Transformative Innovation.** "Transformative Innovation" requires looking beyond the horizon to drive comprehensive changes for future wars. The overall intent is to achieve non-linear outcomes and create a strategic impac**t**. This type of innovation is highly structured, centralised, extremely complex, requires heavy financial outgo, and is undertaken over a long period. Blitzkrieg, Air-Land Battle, and the mechanisation of the Indian Army are apt examples.[43] This type of change has effectiveness at its core.

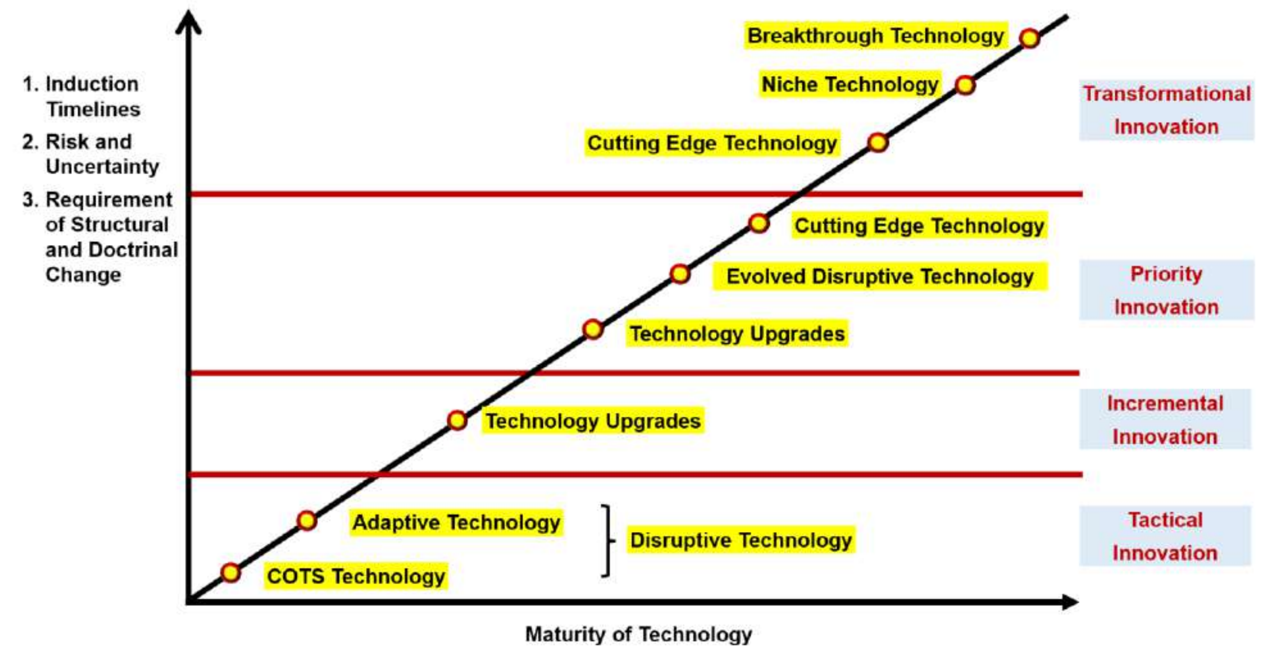

Figure 7: Military Technology and Innovation

Figure 7: The Interplay between Types of Military Technology and Forms of Military Innovation[44]

The above diagram describes the interplay between the types of military technology and forms of military innovation in the armed forces. The X-Axis represents technology maturity levels (TRL and MRL), while the Y-Axis represents induction timelines, risk and uncertainty, and requirements of attendant structural and doctrinal change. Equipment and platforms with mature technologies require less time for induction, pose less risk and uncertainty, and demand little or no structural and doctrinal change for effective absorption by the military.

CHAPTER 5

TECHNOLOGY INFUSION AND THE INDIAN ARMED FORCES

"Innovation no longer remains a choice but has become an imperative."

Narendra Modi,
Hon'ble Prime Minister

Background

In January 1947, even before India became independent, Pandit Jawaharlal Nehru sought advice from Patrick Blackett[45] on the R&D requirements of the Indian military. Blackett played a significant role in convincing Pandit Nehru of the need to establish the Defence Science Organisation (DSO),[46] which came into existence within the Ministry of Defence in 1948.[47] Blackett suggested that a gradual and long-term approach be adopted to develop self-reliance in defence technologies.[48] However, while the Department of Atomic Energy (established 1954) and INCOSPAR[49] (established 1969) gained from the leadership of Dr Homi Bhabha and Dr Vikram Sarabhai respectively, the defence establishment became a victim of bureaucracy.

In the 1950s and 1960s, existing private firms producing military equipment were nationalised and new ones were established as government entities. The entities of Indian MIC have to navigate the MoD bureaucracy, encompassing the Defence Acquisition Council, Defence Procurement Board, Defence Production Board, Defence R&D Board, and rigorous evaluation by the Indian Armed Forces. Other challenges include restricted access to top political leadership, inadequate human resources, poor infrastructure, limited financial support, and stiff and often conflicting specifications. These constraints came to the fore when most projects initiated in the 1980s and 1990s consistently underperformed and overshot development timelines.

The situation is further exacerbated by the virtual monopoly of DRDO over defence R&D, leaving the armed forces without any alternative but to import military equipment. India is in an unenviable position: no other country with such impressive technical capabilities is simultaneously one of the largest importers of military equipment. India aspires to be a Leading Power and to transition from a rule-taker to a rule-shaper by adopting Strategic Autonomy as a key tenet of its approach. However, it is difficult to visualise how India can practise Strategic Autonomy while so extensively dependent on military imports.

Bureaucratic Mind-Set

The civil services do not own a monopoly over the bureaucratic mindset, the military and government-owned entities are equally accountable of this near-universal phenomenon. Bureaucracy represents standardisation under ideal conditions: it collects, retains, and supplies information in an orderly way, but is relatively simple to add to and extremely difficult to prune. As Elting E. Morison observed:

> "In order to make the pattern work, one seeks to eliminate every uncertainty and variable that might disturb the scheme. So, the tendency in every regulating body is to reach out and extend rules over the whole range of human activity. That is why questionnaires get longer and the set of regulations more detailed. That is also why red tape has its unpleasant connotations. It tends to form an increasingly binding set of rules within which a man, an agency, a company has to operate."

In the Indian context, bureaucratic control came with a loss in military effectiveness. Many contend that civil control over the military evolved into bureaucratic control rather than political control. The military too has not developed sufficient expertise in management, technology, business, engineering, and design.[50] Although the Indian Navy has been involved in ship designing since the 1950s[51] and the Indian Army established the Army Design Bureau in August 2016, these initiatives have a long way to go.

It is noteworthy that the Defence Procurement Procedure (DPP), subsequently redesignated as the Defence Acquisition Procedure (DAP), expanded considerably in scope and complexity over time. The document increased from 249 pages in 2006 to 345 pages in 2013, 422 pages in 2016, and 657 pages in 2020, more than doubling in size over a period of fourteen years. While many of these additions sought to enhance transparency, indigenisation, and procedural safeguards, the growing complexity of the framework has often been criticised for lengthening acquisition timelines and reinforcing a process-centric approach. In this sense, the acquisition system risks becoming an end in itself rather than a means to deliver capability in a timely manner.

Several analysts have argued that the DPP/DAP, though intended as a policy framework, has increasingly been treated as a rigid procedural manual, thereby constraining flexibility and efficiency in defence procurement.[52] Evolution of DPP/DAP are as under:

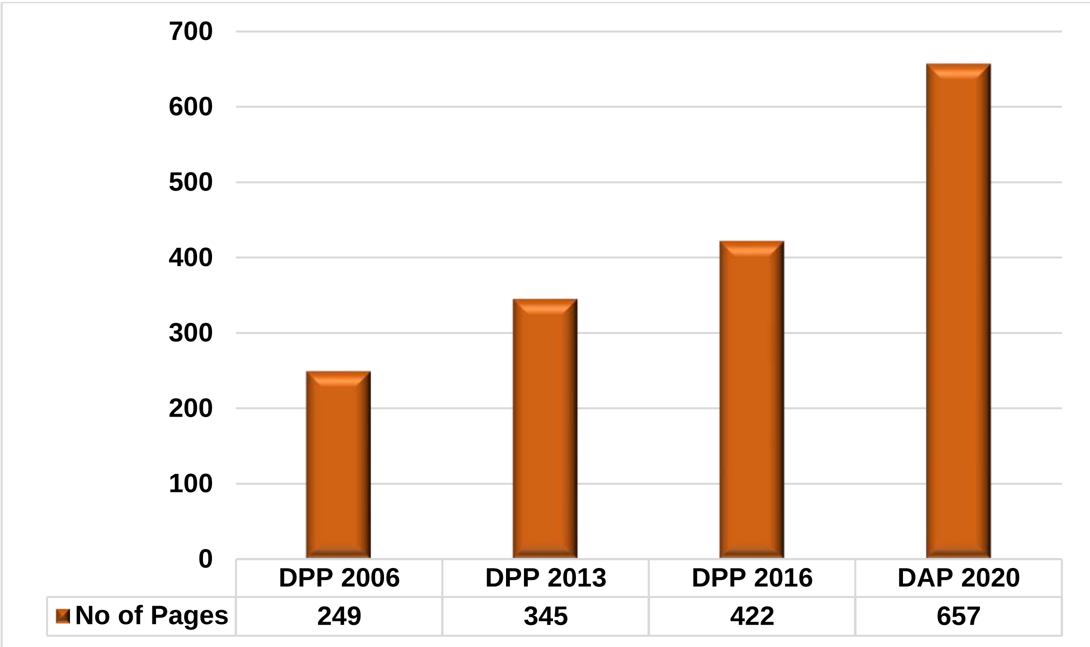

Figure 8: Evolution of DPP/DAP

Figure 8. Evolution of the Defence Procurement Procedure/Defence Acquisition Procedure (DPP/DAP) [53]

How Militaries Innovate

Andrew Marshall opined that even though major militaries have relevant technologies, each nation exploits them in different ways[54], and further, that every nation more or less copies the most successful military innovation.[55] For instance, during the 1970s, the Soviet Union used American technological ascendancy as a conceptual framework for their doctrinal innovation, which they named Military-Technological Revolution (MTR).[56] The Americans took the lead in developing RMA-type precision munitions, yet the term RMA was coined after the First Gulf War.[57] The Israelis were the first to exploit modern technology in combat[58] without reforming their doctrine, regarding precision-guided weapons as force multipliers.[59]

China made the modernisation of the People's Liberation Army (PLA) a priority in the early 1990s.[60] The PLA developed a fifteen-year undertaking to jump two to three generations of military technology, breaking larger defence consortia into smaller groupings to promote competition.[61] In the initial stages, the PLA undertook incremental innovation by incorporating imported components with enhanced technology features into existing platforms, reducing technology development timelines through emulation and adoption.

In the Indian context, experts opine that even during the pre-independence era, the Indian Army relied heavily on surplus equipment from the British Army.[62] Post-independence, during the 1962 Sino-India War, the Indian Army found itself ill-equipped. During the 1965 War, India faced an enemy equipped with superior M-48 Patton Tanks and F-86 Sabre Jets. Historical legacy therefore drives the Indian military to seek technologically superior weapons. However, it has also been commented upon that Indian military modernisation is devoid of political guidance, lacks long-term planning, is constrained by single-service doctrines, and suffers from a mismatch between strategic objectives and the pursuit of new technology.[63]

Current Status

In May 2001, the decision was taken to open defence manufacturing for the Indian private industry, a tacit acknowledgement of the failure of government-owned entities to deliver the wherewithal required for the defence of India. The MoD has been shielding government-owned entities from competition posed by the private sector in defence manufacturing. Most large contracts continue to be awarded to establishments under the Department of Defence Production (DDP). DRDO has not lived up to the expectations of providing desired technologies. The MoD has so far released three Positive Indigenisation Lists as a step towards Atmanirbharta in defence. A few experts have suggested that to overcome this anomaly, entities under the DDP should be moved out of the MoD.

These initiatives suggest a bureaucratic mindset and a bias against the private sector. While Atmanirbharta is a statement of intent of the political leadership, the bureaucracy needs to appreciate that the same cannot be achieved by merely releasing Positive Indigenisation Lists or setting targets for exports. The requirement is to acknowledge the role of technology in the Indian Armed Forces and thereafter develop a policy for technology infusion.

CHAPTER 6

THE WAY AHEAD FOR TECHNOLOGY INFUSION IN THE INDIAN ARMED FORCES

"Technology will become the key driver of future wars."

General M. M. Naravane

Technology Trends from the Russia-Ukraine Conflict

Infusion of technology in the military must provide an asymmetric advantage on the battlefield and contribute towards military effectiveness. Emerging trends from the Russia-Ukraine conflict suggest the following:

- Conflicts will continue to involve the physical mass of troops in hundreds of thousands, and millions of machines and munitions.[64]

- Weight of fires (massed fires) is important, since single munitions precision strikes often fail to destroy their target. Rocket artillery has been significantly effective in the operational depth.

- The battlefield is becoming increasingly transparent. Militaries will need to prioritise detection of the enemy before being spotted, to blind hostile sensors, and to disrupt the enemy's means of sharing data across the battlefield.[65]

- Finding dynamic or mobile targets will continue to be a challenge. Most Russian airstrikes have been against static targets.[66] The Ukrainian kill chain has been hampered by Russian Electronic Warfare (EW) complexes.[67]

- Drones are vulnerable to air defence systems, air attacks, and EW.[68] The average lifespan of a Ukrainian UAV was reportedly a mere seven days.[69] Where it is not possible to target the flying drone through EW, the Ground Control Station (GCS) is often targeted.[70]

- The actual lethality of weapons in the conflict has been consistent with casualties in previous wars. In some cases, casualties have actually been lower.[71]

Key Takeaways and Deductions

Significant takeaways from the conflict in the Indian context are as follows:

- Mass or size will continue to play a significant role in future conflicts. Criticism that the Indian military is organised to fight an industrial era war is ill-founded.

- Even though the technology employed may sometimes be new, the results produced are often the same.[72] The impact of technology on the battlefield will be evolutionary rather than revolutionary.

- Locating mobile or dynamic targets will continue to be a challenge.

- Loiter munitions and low-cost dispensable drones (quadcopters) have democratised the vertical dimension. Resource-constrained nations may opt for large inventories of loiter munitions over combat aircraft. However, loiter munitions and drones remain vulnerable to EW, and their payload and lethality are limited.

- Electronic Warfare (EW) will play a significant role in future conflicts.

- Integrating force multipliers into the C4I2SR complex is a costly and challenging affair.[73]

Key deductions from a technological perspective in the Indian context, informed by a Net Assessment of China and Pakistan[74], are as follows:

Dominant trends include: Intelligence, Surveillance, and Reconnaissance (ISR); networked communications (C4I2SR); Electronic Warfare (EW); force protection; and aircraft-independent long-range precision fires and loiter munitions.

Emerging trends include commercial technologies playing an increasing role in developing military capabilities (AI; additive ("3D") manufacturing; synthetic biology;

quantum computing; and robotics) and military-driven technologies almost certain to dominate the future battlefield (directed energy weapons and hypersonic weapons).

Policy Framework

The proposed policy framework seeks to offer broad guidelines to ensure flexibility and dynamism. The past decade has provided numerous examples of India attaining success in the field of technology, including the JAM Trinity (Jan Dhan Yojana, Aadhaar and Mobile number), Universal Payment Interface (UPI), Digi Locker, Digi Yatra, and the Chandrayaan Mission. Tenets of the policy framework for defence procurement are as follows:

- The MoD must issue a procurement policy. DPP promulgates a procedure and not a policy. This policy must guide the interpretation of ambiguities in DPP and facilitate arbitration where required.

- Reduction in categories for procurement in DPP. For imports, the Government-to-Government (G2G) approach and Strategic Partnership (SP) Model must be adopted. For domestic procurement, the categories could be Buy (Indian) where a mature product already exists, and Buy Indian-IDDM (Indigenously Designed, Developed, and Manufactured) where R&D is warranted.

- Detailed Project Report (DPR) approach must be preferred over the DPP, since every acquisition programme is unique. A consultative approach must be adopted by the Department of Defence (DoD) of the MoD to prepare a DPR for every acquisition programme.

- Consultative approach must be adopted under the aegis of DoD to prepare the DPR by incorporating the user, production agencies, DRDO, and finance. Representatives from industry and academia may also be invited where required.

- Funding for R&D should be identified during the DPR stage on the lines of Viability Gap Funding in infrastructure projects, contingent on the project rather than percentages laid down in the DPP.

- Cost of procurement should be established during the DPR stage to dispel the practice of "Benchmarking" and late-stage cost negotiations, thereby introducing transparency.

- Disinvestment in Government Entities. In February 2021, the government announced that DPSUs set for disinvestment include BEML Ltd, GRSE, and Mishra Dhatu Nigam Limited (MIDHANI).[75] Other DPSUs must be disinvested at the earliest, with management control passing to the private sector.

- Even though 100 per cent FDI is permitted in the defence sector, subsidiaries of foreign OEMs are not treated as Indian firms.[76] During the period April 2000 to March 2023, collective FDI equity inflow in the defence industry was reportedly a mere USD 15.78 million. This needs to be addressed.

Managing Technological Innovation

Management of technical innovation calls for calibrating the interplay between types of technology and forms of military innovation. The form of innovation takes precedence over the types of technologies available. A suggested methodology is as follows:

- **Tactical Innovation** should be the preferred choice for operational commands. Going forward, Integrated Theatre Commands (ITCs) should have an integral Tri-Services Technology and Design Bureau (TDB). This would involve: creating a culture of innovation by offering enrolment to members of the civil and government defence industry into the Indian military on the lines of Territorial Forces[77]; making discretionary funding available for R&D derived from commercial technologies; and creating a framework for frugal R&D that is less bureaucratic and accepts some element of subjectivity in financial prudence.

- **Incremental Innovation.** The typical lifespan of military equipment is twenty years, with some equipment lasting over fifty years.[78] Incremental innovation through periodic updates plays an important part in keeping equipment current.

This calls for: evolving from "Know How" to "Know Why" (from licenced production to mastering imported technologies); a competitive environment to drive the defence industry; linkages with global supply chains; and mid-life upgrades[79] as a policy for indigenously developed products.

- **Priority Innovation.** Given the current status of India's Military-Industrial Base, it would be prudent to pursue joint ventures with established global players for R&D and co-production. Collaborative effort reduces timelines, cost, and risk. The "Zorawar" light tank is an apt example of collaborative effort, expected to be developed in under five years. Development of a Multi-Role Helicopter has adopted a similar approach with a tie-up with Safran of France[80] to co design and produce new generation engines. GE-414 engines will be produced in India to power combat aircraft under development.[81]

- **Transformative Innovation.** This treads into the field of "Unknown-Unknowns," where risk and uncertainty dominate. It calls for a multidisciplinary approach through an understanding of operational art, international relations, and historical and cultural studies. Since no nation is likely to share breakthrough technologies, these have to be developed indigenously. Here, the revamped DRDO will play a significant role in conjunction with the MIC.

MIC and Military Civil Fusion (MCF)

The disease inflicting the Indian defence sector is the underdeveloped MIC; high imports and low exports are merely the symptoms. In India, private entities in the defence sector still use dual-use industrial manufacturing facilities and are constrained by a small manufacturing sector, especially in electronics. Efforts must therefore be focused to develop the MIC, for which the key drivers are: (1) assured orders and (2) adequate funding for R&D. A critical question needs to be answered: "Can there be MCF without a MIC?" The answer is clearly no. More initiatives like the Tata Airbus deal to manufacture the C-295 aircraft in India are required, especially in the field of electronics.

Professional Military Education

With the exception of the Indian Navy, the Indian military has so far played a restricted role in collaborating with other entities to enhance its technological threshold. Officers of the Indian Armed Forces are unlikely to replace scientists working in laboratories across diverse fields. However, the military must be able to identify desired capabilities, communicate those requirements to the MIC and academia in the language understood by them, and engage effectively in technology management. Apart from MTech programmes, select officers must undergo structured training to understand TRLs, MRLs, and Project Management as relevant to the defence sector.

Conclusion

While all nations desire "Autarky" or self-sufficiency, India accordingly seeks "Atmanirbharta" in defence, which translates to self-reliance and not self-sufficiency. A mix of foreign and indigenous technologies would need to be absorbed along the value chain to achieve “Atmanirbharta” in defence. No one agency or entity will be able to shepherd multiple stakeholders with divergent worldviews towards self-sufficiency in defence technologies. Hence, the starting point requires a conceptual policy framework devoid of targets and nominated stakeholders.

It also needs to be accepted that seeking indigenous technologies without developing a robust MIC is akin to putting the cart before the horse. Finally, even as the bureaucracy, represented in equal measure by the military and civil officials in the MoD, needs to communicate better with other stakeholders, the decision-makers need to add granularity to how they view technology to avoid developing a "one size fits all" approach.

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[78] The B-52 Stratofortress, still in service with the U.S. Air Force, was manufactured between 1952 and 1962.

[79] The M-1 Abrams tank, in service since 1979, has undergone approximately twenty major and minor upgrades on the same platform.

[80] "Safran and HAL to Form Joint Venture Company to Co-Design and Produce New Generation Helicopter Engines in India," Safran press release, 14 July 2023, accessed 8 September 2023, https://www.safran-group.com/pressroom/safran-hal-vont-creer-coentreprise-concevoir-produire-inde-moteurs-helicoptere-nouvelle-generation-2023-07-14.

[81] Shishir Gupta, "Biden Administration Notifies US Congress About GE-F414 Engine Deal with India," Hindustan Times, 10 August 2023, accessed 8 September 2023, https://www.hindustantimes.com/india-news/biden-administration-notifies-us-congress-about-ge-f414-engine-deal-with-india-101691647148534.html.

About the Author

Major General Rajat Kumar is the Dean, Faculty of Studies & Leadership, Army War College, Mhow. He was commissioned into the Regiment of Artillery in 1993. He has commanded a Rocket Regiment, an Artillery Brigade and an Infantry Brigade. His diverse staff experience includes tenures as Grade 3 Staff Officer (Artillery Brigade), Grade 1 Staff Officer (Rashtriya Rifles Sector), Director at the Directorate of Artillery (Army Headquarters), Colonel General Staff at Headquarters Inspector General Assam Rifles, and Brigadier General Staff at Headquarters Army Training Command. He has also served as the Brigadier Quartermaster of a Strike Formation.

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