Defence Technology and R&D Ecosystems

Harnessing AI, Unmanned Systems, Robotics, Cyber, Electronic Warfare, Space and Quantum Technologies for Military Reforms

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Global conflicts, skirmishes and warfare in the 21st century are being driven more by advances in disruptive military technologies of artificial intelligence (AI), unmanned systems, robotics, cyber capabilities, electronic warfare, space-based systems and quantum science, vis-à-vis the traditional defence technology advances of capability improvements through better design features of weapon platforms, systems and equipment. These emerging technologies are transforming system capabilities. Consequently, they are reorienting the military, including concepts, strategies and doctrines of warfighting; the iterative optimisation, restructuring, generation and composition of military forces; the budget share and resource optimisation, the budget allocation and control; procurement policies, procedures and acquisition models; innovation, research and development (R&D) and industry ecosystems.

India, in an era of geopolitical uncertainties, global contestation and internal security challenges, finds itself facing multiple threats on a multi-

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domain front and is, thus, compelled to expedite the realisation of its own defence technology transition roadmap, as envisaged in its military reform architecture. India's defence reform architecture itself has shifted focus from the traditional emphasis on force optimisation, procurement efficiency and budget constraint strategies to the new paradigm of force restructuring, capability-building and technology-centric self-reliance. This is with a view to undertake future integrated multi-domain operations. The armed forces are, thus, transforming towards a data-driven, network-centric multi-domain warfare.

This article presents a comprehensive and analytical assessment of technology as a driver of defence reforms, with particular emphasis on India. It examines ongoing technological evolution, technology readiness level maturity timelines, institutional and policy frameworks, innovation, R&D and industry ecosystems, funding architecture, capability gaps and a long-term roadmap, while citing global comparisons. In essence, the analysis focuses on India's defence technology ecosystem, reform trajectory and strategic imperatives.

Keywords: *Disruptive Military Technologies; Warfighting Doctrines; Integrated Multi-domain Operations; Military Reform Architecture; Technology Readiness Level; India's Defence Technology Ecosystem; Reform Trajectory and Strategic Imperatives*

Introduction

Platform-centric to Technology-centric Warfare

Contemporary conflicts, skirmishes and wars are increasingly characterised by the achievement of surprise through higher speed of operations, deep precision strikes, higher autonomy and information dominance.[1] This decisive aspect was earlier achieved with the sheer quantity and quality of weapon platforms and systems. However, in order to undertake integrated multi-domain operations (MDOs) in future, the ability to integrate sensors, shooters and decision-makers within and amongst these domains through the use of flexible networks and intelligent systems is quintessential. This change is often referred to as a shift from the erstwhile industrial-age warfare to a future algorithmic warfare,[2] whose characteristics include:

1. Real-time fusion of Intelligence, Surveillance and Reconnaissance (ISR) to drive evidence-based data-centric operations.
2. Artificial intelligence (AI)-enabled predictive analytics to gain decision superiority in battlefield operations, logistics, sustenance and maintenance.

3. Intra-domain and inter-domain integration (land, air, sea, cyber, space, cognitive and electromagnetic spectrum domains).
4. Unmanned (autonomous and semi-autonomous) combat systems.
5. Relentless cyber and information warfare by both offensive and defensive means.

For India, transitioning to an algorithmic-era warfare, amidst insufficient defence research and development (R&D) spending, disjointed and fragmented innovation, R&D and industry ecosystem and high import dependence, is extremely challenging. Yet, 2025 provided a fleeting opportunity to reorient, restructure and evolve technology-led transformative defence reforms to provide a combat-ready future force that can address multi-domain threats on land, sea, air, space and cyber domains. The year 2025, thus, offered an inflection point: a chance to review past reforms; address the implementation acceleration required; and chart out a path for reforms that are institutional and progressive.

Objective

The article dwells upon the entire spectrum of defence technology ecosystem and includes: emerging and disruptive technologies; R&D; defence innovations, design and engineering; scalable marketable industrial solutions; manufacturing; technology readiness levels (TRLs); defence budgets; acquisitions and procurement systems; supportive institutional and policy frameworks; and financing architectures for R&D and innovations. In addition, it examines emerging disruptive technology ecosystems of India and leading countries of the world, identifying the gaps in processes, capability and technology as pertaining to India. It also draws out technology roadmaps to achieve India's enunciated military reforms. Finally, it suggests implementable recommendations and policy frameworks to achieve India's future defence technology ecosystem, military reform trajectory and strategic imperatives for 2026–2045.

India's Defence Reforms Architecture: Evolution

Past Reforms Paradigm

India's defence reforms, till a decade back, were focused on:[3]

1. *Force optimisation*: This involved streamlining force structures to maximise combat potential of existing assets, while remaining within

budgetary constraints. It aimed at achieving 'right sizing' by reducing manpower where technology had enabled enhancement in capabilities. Notwithstanding, this often resulted in 'downsizing' of old systems to afford new ones. In the context of the Indian Armed Forces, it manifested in pushing for a higher tooth-to-tail ratio and effecting savings for carrying out occasional retro-fitment to equipment, which, in turn, enabled maximising the combat potential of existing weapon platforms and systems.

2. *Procurement efficiencies*: These improved progressively by the incorporation of revised or new provisions in successive editions of the Defence Procurement Procedure (DPP) manual.
3. *Budget optimisation and control*: This was achieved by making the allotments where they were needed the most, and as per the priorities arrived at by the service headquarters. Further, initial allotments were restricted for either release at the revised estimation stage or for undertaking readjustments within the allottees as per requirements. This ensured effective control of funds by disbursing authorities, as also effective control of procurements by respective certified financial authorities. The funds were, thus, released only after the allotted funds had been exhausted and the forecasted requirements inescapable.

Consequently, these reforms remained platform-centric and were more reactive in nature due to constrained budgets, thereby only improving the procedural efficiency at best.

Focus on Technology-led Reforms

Since the mid-2014 onwards, India, in consonance with the national development plans of NITI Aayog and in pursuit of its goal of self-reliance, embarked on a multi-pronged campaign, launching several near-synchronised flagship programmes. These programmes included: 'Make in India' to strengthen domestic manufacturing; 'Skill India' to train a future-ready multi-sector workforce; 'Digital India' to promote digital literacy; 'Startup India' to support start-ups, innovations and entrepreneurial culture; 'Invest India' to simplify the environment for investors; and 'Atmanirbhar Bharat' to make Indians independent and self-sufficient in all senses. A clarion call was made to progress towards a 'Viksit and Saksham Bharat'—implying a competent and developed India by 2047 (the 100th year of independent India).[4] Further, after the articulation of Atmanirbhar Bharat in 2020 and the

promulgation of *Defence Acquisition Procedure (DAP) 2020*, India's defence reforms have and are undergoing technology-led structural transformation:

1. *Modernisation planning*: With a view to capitalise on the ever-shrinking technology development cycles and the consequent weapon development programmes, India's defence planners replaced the erstwhile 15-year Long-Term Integrated Perspective Plan (LTIPP) by a shorter duration 10-year Integrated Capability Development System (ICADS) for the three Services. This endeavoured to accelerate the ongoing technology-led reform changes. The Integrated Capability Development Plan (ICDP) of the three Services further maximised resource optimisation and infused integration and jointness in the tri-services planning and procurement process. This initiative is, thus, a part of a broader strategy to enhance India's defence capabilities through effective coordination amongst the armed forces organisations, institutions and agencies. The ICDP is expected to facilitate strategic planning, capability development, defence diplomacy and indigenisation in the defence sector.[5]
2. *Technology-centric defence capabilities*: The ICADS and the Technology Perspective Capability Roadmap (TPCR) are closely linked to India's defence strategy. The ICDP outlines the long-term capability requirements of the armed forces, while the TPCR provides a roadmap for future technology and capability requirements by focusing on emerging combat technologies. These documents collectively guide the Indian government in shaping its defence capabilities and ensuring their technological advancement.[6]
3. *Self-reliance*: Indigenous design, development and manufacturing of systems and platforms have been prioritised. The 2025 edition of the TPCR emphasises the need for indigenisation and self-reliance in defence technologies, in consonance with the objectives of the 'Make in India' initiative.
4. *Integrated operations*: There is also a persistent push towards theatre commands and joint MDO doctrine. Further, both the TPCR and joint MDO doctrine aim to enhance military's readiness against multi-domain threats, thereby ensuring that the defence sector is equipped to address all future challenges.[7]
5. *Evolving an innovation ecosystem*: Institutionalisation of start-ups and micro, small and medium enterprises (MSMEs) participation is being ensured through provisions incorporated in successive editions of DAP 2020 and Draft DAP 2026.

6. *Export orientation*: India's defence ecosystem is also endeavouring to make India a major defence exporter in the near future.

Considering the long gestation period required for implementing the change, the Indian Army has identified 2023–2032 as the 'decade of transformation'. This comes in the backdrop of the Indian Army's 'year of transformation' (2023), 'year of technology absorption' (2024) and the 'year of reforms' (2025).[8]

Defence Technology and Research and Development (R&D) Ecosystem

The defence technology and R&D ecosystem is a network of research resources, comprising military and civil, public and private, national and international—universities, research institutes/centres/organisations, industries/businesses, government ministries/agencies and individuals (innovators, angel investors, venture capitalists)—that drive innovation activities and technological development.[9] These stakeholders form partnerships and work in collaborative R&D networks to create new defence knowledge/technologies/ideas to develop solutions and transform these into viable defence products or services.[10]

Building such a defence ecosystem involves: developing high-quality education capabilities in schools and higher education institutes (HEIs); facilitating basic, applied and developmental research activities in universities; promoting science, technology and innovation in research institutes/centres/organisations; skilling to design and develop products and services by design agencies; acquiring high-end engineering machinery, foundational metals/materials and technology; progressive advancements towards maturity/optimum TRLs in manufacturing processes; and filling technology gaps by collaborating with foreign partners to procure critical or strategic technologies to drive novelty, enhance productivity, improve quality and ensure sustainability.[11]

The strategic foresight of defence planners and leaders, long-term strategic outlay/investments to build R&D resources, training a future-ready skilled workforce to drive innovations and technologies, supportive government policies, industry partnerships and stakeholders' collaborative synergy to build in-house technological progress and industry teamwork to foster innovations are quintessential for the rise, growth and success of defence technology and R&D ecosystem.[12] India, with global aspirations, is

shaping its defence R&D ecosystem to develop and incorporate emerging defence technologies of AI, unmanned combat systems, including robotics, hypersonics, cyber space and quantum technology, as the new frontiers and drivers to accelerate its defence reforms.

Defence Innovation Ecosystem

1. *Innovations for Defence Excellence* (iDEX): This scheme was launched in 2018 by the Department of Defence Production (DDP) of the Ministry of Defence (MoD), Government of India. It provides for an ecosystem to foster innovation and technology development in defence and aerospace sectors by engaging innovators and entrepreneurs to deliver technologically advanced solutions for modernising the Indian military. The iDEX engages industries, MSMEs, start-ups, individual innovators, R&D institutes and academia and provides them grants/funding and other support to carry out R&D which has good potential for future adoption by the military.[13] The core objectives are to: facilitate rapid development of new, home-grown and innovative technologies to meet the needs of the military in shorter timelines; create a culture of engagement with innovative start-ups to encourage co-creation; and empower a culture of technology and co-innovation within the defence sector.[14] The iDEX, since its inception till 2025, has undertaken over 50 editions of Defence India Start-up Challenge (DISC) and Open Challenges. In this period, it received 10,000+ applications, shortlisted 400+ applicants (for further evaluation and support), announced 250+ winners across different challenge categories, signed around 650 contracts and approved grants worth Rs 3,000 crore (about US$ 344 million) to support innovation in defence.[15]
2. *Technology Development Fund* (TDF): The scheme, launched in 2018 by the Defence Research and Development Organisation (DRDO), extends financial support and expertise to upgrade existing defence products/systems, processes and their applications, thereby reducing production costs, improving functionality and quality and promoting Make in India for development of futuristic technologies with defence applications. The scheme lists requirements of the service headquarters of upgrading products/systems and futuristic defence technologies as projects for which eligible stakeholders apply. The TDF, from 2018 to 2025, has sanctioned 78 projects, amounting to about Rs 333.21 crore (3,332.1 million). Of these, 27 technologies in 10 projects have already been developed successfully.[16]

3. *Services innovation ecosystem*: The three services of the armed forces have their own innovation organisations, which identify service-specific requirements of future defence technologies, products and systems. Through institutionalised mechanisms, these requirements are disseminated to the national R&D ecosystem in the form of: 'Innovation Challenges' to the iDEX; 'Technology Development Projects' to the DRDO; 'Import Substitution of Defence Items/Products' to industries, including start-ups and MSMEs; 'Make Projects' by public sector or private sector or on a public–private partnership (PPP) model; 'Mission Mode Projects' by the DRDO; *de novo* home-grown defence systems or subsystems under the 'Development-cum-Production Partner Route' or the 'Strategic Partnership' (SP) model; and so on. Services also run in-house service-specific 'Ideas and Innovation Competitions' to encourage innovative minds and foster an innovative culture within the services.[17]

Policy Frameworks and Institutional Architecture

Defence Acquisition Overhaul: DAP 2020 and Draft DAP 2026

India is continuously aligning procurement policy frameworks, like the DAP 2020 and the Draft DAP 2026, which represent paradigm shifts towards indigenisation, technology and innovation:[18]

1. *Introduced prioritised 'Buy (Indigenous Design, Development and Manufacturing [IDDM])' category*: The Buy (IDDM) category has been accorded the highest priority amongst the different categories of procurement permitted by the MoD. This has been enunciated in both DAP 2020 and Draft DAP 2026 for accelerating indigenous design and production capabilities.
2. *Introduced 'technologies of tomorrow'*: Provisions specifically for AI, robotics, cyber and other advanced domains have been incorporated.
3. *Make-I, Make-II, Make-III frameworks*: These enable government-funded and industry-funded R&D to promote indigenisation and self-reliance.
4. *Leasing and fast-track procurement*: Procurement and innovation-friendly provisions promote early technology absorption.
5. *Speed up acquisition cycles*: Constantly encouraging private sector participation, including MSMEs and deep-tech firms, besides enabling foreign company subsidiaries to qualify as local vendors to boost technology transfer.

6. *Boost self-reliance (Make in India)*: Constantly increasing the share of capital procurement reserved for Indian domestic industry/firms—from 50 per cent in DAP 2020 to 68 per cent in financial year (FY) 2022–2023 to 75 per cent in FY 2023–2024;[19] establishing Defence Industrial Corridors (DICs) in the states of Uttar Pradesh and Tamil Nadu to enable them to become innovation hubs; and the corporatisation of the defence public sector undertakings (DPSUs) formed out of ordnance factories, like the Yantra India Ltd, to enable autonomy to scale production.
7. *Exports growth*: India aims to increase defence exports significantly by 2030 and beyond, supported by domestic production volume growth and global demand for Indian systems.

Defence Procurement Manual (DPM 2025)

The DPM 2025 has the following features:

1. *Policy document from the MoD*: Restructures revenue procurement procedures for the armed forces.[20]
2. *Decentralises approvals to empower field formations*: Promotes speed, transparency of supply chains and indigenous participation to realise defence reforms and industrial self-reliance.
3. Focuses on *lifecycle costing* and *performance-based logistics*.
4. *Promotes integration of digital procurement systems*: To enhance transparency and reduce delays.

Defence Production and Export Promotion Policy (DPEPP)

The DPEPP is a draft framework for transforming the country into a top global defence manufacturer. It emphasises R&D and rewards innovation/intellectual property (IP). It also promotes private sector participation by recommending foreign direct investment (FDI) liberalisation (currently at 74 per cent through the direct route and 100 per cent through the government route). By 2029, it aims to target Rs 3,00,000 crore (US$ 25 billion) in defence production and Rs 50,000 crore (US$ 5 billion) in exports.[21]

TPCR 2025

The TPCR 2025 is a long-term strategic roadmap that outlines future force capability requirements and technology priorities across services. It sets a framework for capabilities through the next 10–15 years:[22]

1. *Guide for Indian industry, research institutions and defence planners*: Gives visibility in defence planning horizon of 2026–2035.

2. *Aligns capability with technology*: Long-term capability planning with technological evolution.
3. *Integrates capabilities*: Integrates service-specific and joint capability.
4. *Outlines emerging technology priorities*:
   (i) AI, machine learning and big data: Enabling decision aids; analytics; predictive logistics; and autonomous systems.
   (ii) Unmanned and autonomous platforms: Unmanned ground vehicles (UGVs) for reconnaissance and mine-laying; combat drones; long-range stealth drones (medium-altitude long-endurance [MALE]/ high-altitude long-endurance [HALE]); loitering munitions; counter-drone technology; and networked cyber systems.
   (iii) Cyber and electronic warfare (EW): Cyber-resilient communications and net-centric operations; strengthening defensive and offensive postures, online and in orbit; adaptive jamming; and integrated EW systems.
   (iv) Space and networked systems: Expansion of space-based surveillance satellites to improve threat detection and cue defensive systems; high-altitude pseudo-satellites (HAPS) and stratospheric airships for ISR; continuous connectivity; and quantum communication.

Service-specific Capability Systems

The TPCR 2025 delineates service-specific capability systems as follows:

1. *Army*: Robotic systems for counter-improvised explosive device (IED) and integrated ammunitions; light tanks optimised for high altitudes; and future ready combat vehicles (FRCVs) replacing legacy tanks.
2. *Navy*: Next-generation carriers with electromagnetic aircraft launch systems; autonomous underwater vehicles (AUVs); fast interceptors; and nuclear propulsion systems.
3. *Air Force*: HAPS for persistent ISR, along with laser weapons and stealth bomber drones.

Cross-cutting Technologies

Some cross-cutting technologies highlighted by TCPR 2025 are:

1. *AI-enabled decision support*: Digital twins, simulation platforms enabling real-time operational planning.
2. *Hypersonic missiles*: Include scramjet-powered systems, enhancing deterrence and strike reach.
3. *Chemical, biological, radiological and nuclear systems*: Radiation survivability and decontamination units.

The TPCR 2025, thus, positions India to develop self-reliant, technology-driven forces that leverage advanced automation, unmanned systems and networked capabilities through 2035 and beyond.

Joint Doctrine for Multi-Domain Operations (MDO 2025)

The Joint Doctrine reiterates need for integration, interoperability and data-centricity:

1. *Multi-domain integration framework*: Released by the Raksha Mantri in August 2025, this official doctrine sets an integrated operational framework across land, sea, air, space, cyber and cognitive domains.
2. *Guides future strategy and interoperability*: While not a 'policy' in the fiscal sense, it is an official doctrinal document guiding future defence strategy, warfare concepts and interoperability.
3. *Integrated operations*: Emphasises integrated operations across all domains.
4. *Data-centric*: Focus is on network-centric warfare and decision superiority.[23]

Technology Readiness Levels (TRLs)

TRL Framework in Defence Planning

The TRLs provide an indicative assessment of current structural maturity and future scaling-up requirements to be initiated for full maturity of technology for envisaged applications.[24]

Basic Applied and Developmental Research

1. *TRL 1*: Basic/fundamental research on theoretical scientific properties and principles of specific technology is started and observed by prime academic institutions and research labs/centres/institutes/agencies, which could be directed by national missions/programmes. At this stage, there are no concepts or practical applications of the technology being developed.
2. *TRL 2*: Applied research on the practical concepts/principals of specific technology is hypothesised and formulated through ideas, papers and brainstorming (AI-enabled/quantum science/unmanned/robotic/cyber/space warfare concepts, reforms, joint MDO doctrine, etc.).
3. *TRL 3*: Analytical and experimental validation of applied research in laboratory or proof of concept (for instance, the DRDO–Indian Institute of Technology [IIT] Delhi's demonstration on quantum key distribution [QKD] of about 100 kilometre [km] fiber[25] and the Indian

Space Research Organisation's [ISRO] proof-of-concept experiments on quantum communication[26]).

Technology Validation Testing and Prototyping

1. *TRL 4*: Technology components are validated in controlled laboratory environment (for example, the DRDO's AI-based image analytics for surveillance[27] or autonomous navigation algorithms for UGVs in lab).
2. *TRL 5*: Technology testing in conditions resembling relevant environment (such as the iDEX-supported and developed swarm drone prototypes testing by the Indian Army).
3. *TRL 6*: Prototype system demonstrated in operationally relevant environment conditions (for instance, UGV/robotic mule trials in high-altitude areas[28] and air force's ALFA-S swarm drone system demonstrations).[29]

System-operational Deployment and Scaling

1. *TRL 7*: Near-operational system prototype tested/demonstrated in operational environment, that is, real missions/exercises (for example, AI-enabled ISR systems deployed in Iran and Ukraine conflicts, geosynchronous satellite [GSAT] military communication satellites supporting live operations and deployment of cyber defence platforms).
2. *TRL 8*: System complete, that is, proven, qualified and ready for deployment (for instance, the DRDO's Netra unmanned aerial vehicle [UAV] inducted for surveillance, ASTRA beyond-visual-range missile, with AI-assisted targeting elements,[30] and anti-satellite [ASAT] capability demonstrated under Mission Shakti).
3. *TRL 9*: Actual system fully deployed, used and proven in real operations (such as the operational use of UAVs for AI surveillance along the Line of Actual Control (LAC)/Line of Control (LoC), the integrated space-based ISR with satellites and the Navigation with Indian Constellation [NavIC][31]).

TRL-based Strategic Implication of Key Technologies

The select six disruptive technologies in military warfare endeavour to achieve decision dominance through use of AI; strategic deterrence employing quantum science applications; reduced manpower dependency by effective use of robotics; swarm warfare using autonomous systems; persistent conflict dominance employing cyber and EW; besides space for ISR dominance and

space control. Currently, India lags in quantum and advanced autonomy but is progressing rapidly in AI, space and cyber.

Domain-wise Defence Technology Analysis (India in 2026)

Artificial Intelligence

Artificial intelligence is central to future warfare in terms of battlefield ISR fusion analytics, target recognition, decision-support systems, employment of autonomous weapon systems and management of logistics and predictive maintenance. India, accordingly, has set up its AI Task Force and the Defence AI Council; undertaken a number of DRDO projects in computer vision, natural language processing (NLP) and autonomous systems; and also been increasing startup participation via the iDEX. Estimates of 2026 put India at mid-TRL 6–8, with requirement to scale up AI for large-scale operational integration. The AI systems have largely matured for narrow tasks of image/voice recognition, logistics optimisation and so on, with many AI tools at TRL 8–9 in military use, that is, surveillance analysis and predictive maintenance.[32] Full 'true autonomy' (systems acting with no human link) is nascent and at the R&D stage. Doctrines aim to reach higher autonomy by 2035, with autonomous ISR drones learning from missions.[33]

Quantum Technologies

Quantum sciences applications in India include quantum sensing and navigation and quantum communication. India has set up its National Quantum Mission; and the DRDO has undertaken collaborations with academic institutions. Quantum developments are at low TRL stage and India, consequently, has a limited quantum industrial base. Currently, most quantum technology is at TRL 2–4 (laboratory and few prototypes).[34] Quantum sensing (magnetometers, clocks) is the most advanced quantum technology field (experiments in field are likely by 2030). Quantum communications (QKD) have been demonstrated but wide deployment awaits infrastructure (full satellite QKD not expected before 2030). Large-scale quantum computing remains a future task (50–1,000 qubits by 2030).[35] Meanwhile, post-quantum cryptography (PQC) is being standardised—the United States (US) is planning full migration by around 2035.[36]

In January 2026, the then Chief of Defence Staff (CDS), General Anil Chauhan, released the 'Military Quantum Mission Policy Framework' to integrate quantum sensing, communication, computing and materials into the armed forces, aligned with India's National Quantum Mission.[37]

Unmanned and Autonomous Systems

Unmanned and autonomous systems applications in India include: UGVs for logistics (high-altitude area mules, etc.), mine breaching and reconnaissance; UAVs and UAV swarms; and loitering munitions in combat. India has seen rapid development in this field from 2020 onwards; and in 2026, as derived from ongoing status, unmanned and autonomous systems are at prototyping to testing in near operational environments i.e. TRL 5–7[38] while Unmanned vehicles for reconnaissance (drones, UGVs) are getting widely fielded and thus at TRL 7–9.[39] Aggressive autonomy (swarming drones, robotic combat vehicles) is still experimental at TRL 3–5, and is being tested in exercises.[40] Several private start-ups and now a few primes have become active. India, today, lacks in engine technology, high-end autonomy algorithms and stealth technology.[41]

Robotics

Robotics applications in India include robots to be used for reducing manpower dependency, especially in combat, and for explosive ordnance disposal. India has seen rapid growth in this field and, presently, is at TRL 6–7. Semi-autonomous ground robots (surveillance/IED disposal) are being used in limited roles. Currently, several private players have become active in this field.

Cyber and EW

Cyber and EW is a persistent conflict domain and involves offensive and defensive measures. India, since establishing the Defence Cyber Agency, has grown in its capabilities; and in 2026, the country is at TRL 7–9. Core cyber defence (firewalls, encryption and intrusion detection) is mature at TRL 9. Frontier areas, such as AI-driven cybersecurity tools and quantum crypto analysis, are also evolving. Further, India is strong in its offensive cyber operations, cyber resilience and infrastructure protection. Concurrently, India's Computer Emergency Response Team (CERT-In) frameworks and the Defence Cyber Agency are being expanded for cyber command status with private sector capacity-building.

The National Cyber Security Coordinator (NCSC) office,[42] a part of the National Security Council Secretariat (NSCS), has emerged out of the 2013 reform. It has the primary coordinating role for domestic cybersecurity. The NCSC guides the National Security Adviser (NSA) and supports in shaping domestic cybersecurity policies, mitigating current threats and preparing to address future cyberthreats. The NCSC also oversees the National Cyber

Coordination Centre (NCCC) and the National Critical Information Infrastructure Protection Centre (NCIIPC). The NCCC generates essential situational awareness and facilitates timely information sharing to protect against cyberthreats, while the NCIIPC focuses on safeguarding critical infrastructure from cyberattacks. Indeed, the NCSC office emphasises the importance of a collaborative approach to cybersecurity.

Space Technologies

India's progress in space technologies has been good, especially for ISR, navigation and in military satellites. The ISRO and the Defence Space Agency have established good synergy; for instance, in 2019, India demonstrated its ASAT capabilities. In 2026, in the field of space technologies, the country is at TRL 6–8.[43]

It is thus evident that though India lags in quantum and advanced autonomy in 2026, it is progressing rapidly in AI, space and cyber.

Indian Defence Ecosystem: Structure and Stakeholders

Ecosystem Primary Structure

1. *MoD*: The ministry is responsible for formulating and progressively revising the ecosystem's policy and provision of funds.
2. *DRDO*: It is the primary defence R&D agency, with over 50 laboratories, and is organised into technology clusters to foster self-reliance in defence technologies.
3. *DDP*: This department provides production oversight to the ecosystem.
4. *DPSUs/Ordnance Factory Board* (OFB): These are corporatised entities and provide the manufacturing backbone.

Ecosystem Secondary Structure

1. *Private sector primes*: Primes undertaking significant R&D in defence technology include Larsen & Toubro (L&T), Tata, Mahindra Defence and Bharat Forge.
2. *MSMEs*: Currently, about 16,000+ MSMEs[44] feed primes as tier-2 defence suppliers, enabling import substitution of a number of components parts and subsystems through reverse engineering.
3. *Defence start-ups*: These range up to about 1,000[45] and develop niche technologies independently or through the iDEX scheme.
4. *Academia*: This includes HEIs of repute, such as the IITs, the Indian Institute of Science (IISc) and others. They drive basic and applied

research in defence technologies and developmental research, in collaboration with the DRDO/DPSU/OFB/private sector research labs/centres, which, in turn, also drive TRL 4–9, that is, technology, prototyping and operational developments.

5. *Anusandhan National Research Foundation (ANRF)*: It is the apex body that provides high-level strategic direction for scientific research, innovation and entrepreneurship in the fields of natural sciences, including mathematical sciences, engineering and technology, environmental and earth sciences, health and agriculture. It envisages spending Rs 50,000 crore (Rs 500,000 million) over five years (2023–2028), out of which Rs 36,000 crore (Rs 360,000 million), almost 80 per cent, is expected to come from non-government sources, including industries and both domestic and outside philanthropists.[46] The Department of Science & Technology (DST) administers the ANRF and it is governed by a board consisting of eminent researchers and professionals across disciplines. Since the scope of the ANRF is wide-ranging—impacting all ministries—the prime minister is the ex-officio president of the board and union ministers of science and technology and education are the ex-officio vice presidents. The ANRF's functioning is governed by an executive council chaired by the Principal Scientific Adviser to the Government of India.[47]

Stakeholders Functional Roles

1. *Academia and national laboratories*: Traditionally responsible for fundamental and applied research, the IISc, the IITs and science institutes (Council of Scientific and Industrial Research [CSIR] labs, Defence Institute of Advanced Technology [DIAT], Research Centre Imarat [RCI], etc.) contribute foundational research in emerging technologies (such as AI algorithms, robotics and quantum physics). They partner via sponsored projects and hackathons. However, historically, civilian academia in India has had minimal direct defence collaboration. Recent academia–R&D linkages, such as DRDO academic chairs, technology clusters and shared lab facilities are bridging this. Defence investments at universities are planned to boost relevant R&D.
2. *DRDO*: This organisation carries out primary core research and prototyping. It funds projects from TRL 2 to TRL 7, in-house and via the TDF. Labs, like the Aeronautical Development Establishment (ADE; aeronautics), DLRL and LRDE (electronics), RCI (close-in weapon systems) and Institute of Nuclear Medicine and Allied Sciences (INMAS;

warfare medicine), and new centres of excellence (CoEs; in AI, robotics, quantum) collaborate with the private sector.

3. *Start-ups and MSMEs*: They develop niche emerging disruptive technologies for integration. Some programmes, like the iDEX and DISC, engage them. These small enterprises excel in composites, sensors, software and unmanned technology. However, they face several hurdles, such as funding gaps beyond grants, long certification cycles and export licence complexities. Incubators, like NSRCEL–IISc and i-Hub–DRDO in the IITs, and industry bodies now mentor start-ups. India's iDEX has funded many early stage firms.
4. *Private sector*: These companies undertake innovation and system integration, and are entering shipbuilding, aircraft engines, missiles and cyber. They invest in R&D centres, often funded via government co-financing. However, co-development culture is nascent. Industry lobbies (such as Confederation of Indian Industry [CII] and Federation of Indian Chambers of Commerce and Industry [FICCI] Defence) are advocating further policy clarity, easier licensing (such as revised industrial licensing) and acquisition of IP from start-ups.
5. *DPSUs*: These units execute production and are responsible for scaling up large projects. The DPSUs are now co-owners of Defence Innovation Organisation (DIO), and also collaborate with partner incubators. They are increasingly teaming up with private small and medium-sized enterprises (SMEs) under the SP model (for example, the Hindustan Aeronautics Limited's [HAL] chopper programme with partners). The DPSUs are expected to boost joint ventures and enable technology absorption.
6. *Investors and industry funds*: Venture capital/private equity interest in defence technology is growing, with a record US$ 247 million being raised in 2025.[48] Government policies, such as sovereign co-investment through India-US joint innovation fund i.e. 'Innovate in India Fund' under Defence Innovation Unit (DIU) of US and tax incentives, are enablers. However, the investors remain cautious due to market risk and export controls. Notwithstanding, the discipline now with more than $100 million in deep tech is growing.[49]
7. *Services*: As the end users of defence equipment, the services set priorities and requirements, as well as enable trials and operational deployment of prototype systems. They also forecast requirements through concepts, doctrines, ICDP, TPCR and so on.

Defence Budget and R&D Financing Architecture

Budget Overview and Funding Channels

India's defence budget of FY 2027 stands at 2 per cent of gross domestic product (GDP).[50] This is lower than 3 per cent of GDP recommended by the Standing Committee on Defence in 2018. Spending on capital expenditure in the last decade has averaged 27 per cent of defence budget, against the recommended 40 per cent. Further, the capital outlay has persistently been skewed against the revenue imbalance. Also, in recent years, the proportion of defence budget to R&D has declined. R&D accounted 4.7 per cent of defence expenditure in 2014-15 and as per budget estimates for 2026-27 is projected to account for 3.7 per cent of the defence expenditure. This is relatively very low against global benchmarks.

1. *DRDO budget allocations*: The capital and R&D outlays of Rs 14,000+ crore (140,000 million) in FY 2025–2026 aim to accelerate defence technology development in DRDO labs and other defence establishments with a view to reduce imports.[51] In India, DRDO labs, like Centre for Artificial Intelligence and Robotics (CAIR) and RCI, and DPSUs, like HAL and Bharat Electronics Limited (BEL), lead defence research and are increasingly partnering with private firms. Major funding sources include: national science and technology budgets, such as India's National Quantum Mission at Rs 6,000 crore (60,000 million) up to 2030;[52] defence R&D funds, like the TDF; and dedicated innovation grants, such as the iDEX and DISC funds.
2. *Indian industry*: Large business groups, like Tata and L&T, and hundreds of start-ups, like ideaForge and Grene Robotics, are now targeting for defence products.[53] Academia is also being increasingly engaged via new institutes, such as defence AI research centres in top universities, thematic quantum hubs[54] and collaborative programmes, like iDEX incubators and defence technology cells. The funding is mixed: traditional R&D budgets, new venture-like funds and challenge prizes, like the iDEX's Support for Prototype and Research Kickstart (SPARK) grant,[55] provide capital and procurement pathways for innovations.
3. *iDEX grants*: These are in the range of Rs 1.5 to Rs 10 crore (15 to 100 million) and are part of the DISC and the SPARK framework. Both engage industries, including start-ups and MSMEs, R&D institutes and academia to foster innovation in aerospace and defence sector.
4. *TDF funding*: Funding of up to Rs 50 crore (500 million) per project, having a duration of up to 4 years for project development, is available for MSMEs and start-ups.

5. *R&D funding schemes*: A Rs 1 lakh crore (100,000 million) 'Research Development and Innovation Fund' supports DPSUs, private firms, MSMEs and start-ups.[56]
6. *PPP and co-development models funding*: These are financed out of the funds made available for defence projects under the Make I, Make II and SP frameworks.

Comparative Global Framework

1. *The US*: The US Department of Defense's Research Development Test and Evaluation (RDT&E) budget is US$ 179 billion for FY 2026,[57] and funds basic and applied projects in AI/autonomy, hypersonics, space, directed energy and contested logistics. The Pentagon has recently elevated 'Quantum and Battlefield Information Dominance' category alongside AI and other emerging techs.[58] The Defense Advanced Research Projects Agency (DARPA) drives most of the US high-risk R&D projects. DARPA's share of DOD research, development, testing, and evaluation funding (budget categories 6.1 through 6.7) has declined from 6.4 per cent in FY1996 to 3.3 per cent in FY2021.[59]
2. *China*: China has entrenched AI and quantum technologies at the core of its defence-industrial strategy. China's 2026–2030 Five-Year Plan clearly targets quantum leadership and an 'AI+' action plan.[60] It calls for scalable quantum computers, an integrated space-cum-ground quantum network, 6G, humanoid robotics and advanced semiconductors. The People's Liberation Army's (PLA) research institutes (such as China Aerospace Science and Technology Corporation [CASC], China Electronics Technology Group Corporation [CETC] and PLA Academy of Military Science) work on AI-enabled systems, cyberwarfare tools, ASAT weapons and next-generation missiles. China's R&D budget has always been ambiguous, but is likely to be tens of billions of US dollar. Under technology sanctions, China emphasises indigenous innovation, such as in defence chips, and dual-use civilian–military fusion.
3. *The European Union (EU)*: The EU has ramped up its joint R&D. The European Defence Fund (EDF) has provided 8 billion for collaborative defence R&D for the period 2021–2027, making it the third-largest defence R&D budget in the EU.[61] The EDF has funded 224 projects with 700+ entities, including many SMEs. Key technology areas include AI, autonomous systems, drones, cyber and hypersonics. The proposed EDF 2.0 envisions a much larger post-2028 programme—a 125 billion defence/space fund within a new European Competitiveness Fund—though final commitment is pending.

4. *North Atlantic Treaty Organization (NATO)*: The organisation has created pan-Atlantic innovation mechanisms, like the Defence Innovation Accelerator for the North Atlantic (DIANA) and a 1 billion multi-sovereign NATO Innovation Fund.[62] The NATO's strategy emphasises transatlantic interoperability and responsible AI (three of the six principles include lawfulness, human oversight and bias mitigation).[63] The EU and the NATO are collaborating on supply-chain resilience and issue standards for small unmanned aerial systems. They have also established forums, like the Partnership for Indo-Pacific Industrial Resilience (PIPIR)—an alliance of 14 countries from the Asia-Pacific to Euro-Atlantic—to strengthen key technology supply chains and co-production.
5. *Israel*: The country has a mature defence technology ecosystem. Though its total defence budget of US$ 20 billion is small relative to great powers, Israel allocates a high percentage to R&D. Its defence R&D directorate (MAFAT) directly engages hundreds of start-ups. In 2025, Israeli defence start-ups won New Israeli Shekel (NIS) 1.08 billion (US$ 300 million) in orders (25 per cent from exports).[64] The MAFAT works with 221 companies out of 300 in the sector, many at very early stages. Priority domains are UAVs and autonomous systems, AI and digital and cyber, in that order. Israel's industry leaders (Israel Aerospace Industries [IAI], Elbit Systems and Rafael Advanced Defense Systems) and start-ups (UVeye and Sightec) are active in combat robotics, missile defence, cyber and Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR). The regional conflicts of 2025 and 2026 has further accelerated the adoption of drones and AI for counter-drone and decision support.

Gap Analysis: Defence Technologies Ecosystem in India

India requires strategic reserves and domestic processing capability for rare earth elements. It also needs to scale up indigenous production of semiconductors and advanced material alloys required for defence products. Further, it is necessary for the country to reduce dependence on imports, especially through China-dominated supply chains, as also diversify its sources.

The defence ecosystem faces major gaps in talent and skilling. There is a need for domain specialists, such as AI engineers, data scientists, quantum physicists,[65] robotics experts, cyber operators and specialists. It is, therefore,

important to build defence technology universities with specific defence technology curricula. Lateral entry of tech experts into the armed forces must also be encouraged. In addition, India is lagging in defence technology ecosystem infrastructure. The requirements include test ranges, simulation labs and AI compute infrastructure.

For India, despite advancements in the application of emerging disruptive technologies for military use, capability gaps remain in critical areas, such as the indigenisation of jet engines and advanced materials, especially for semiconductors and active electronically scanned array (AESA) chips for radars. These, in turn, indicate the need for advanced R&D. Currently, the army is unable to scale up to meet the requirements for modern loitering munitions; the navy is still seeking next-generation anti-submarine warfare (ASW) autonomous vehicles; and the air force requires AI-driven swarming drones. The identified gaps across domains are as follows:

Capability Gaps across Emerging Defence Technologies (India in 2026)

1. *AI gaps*: There is a need for strong algorithms for surveillance video analysis and multitarget tracking, as well as NLP for multilingual intelligence.
2. *Quantum gaps*: India, currently, has few fielded quantum systems. A gap exists in secure communications; high-precision navigation independent of GPS; and intelligence from quantum sensors (magnetometers, clocks).
3. *Robotics/unmanned system gaps*: Smaller UAVs are in use, but fully autonomous swarms are nascent. There are gaps in ground robotics (autonomous supply convoys or explosive ordnance disposal) and underwater drones (Indian Navy's special warfare underwater vehicles [SWUVs]) for surveillance and ASW.
4. *Cyber and EW gaps*: India has improved its cyber posture, but faces shortages of trained cyber warriors, as well as low maturity in real-time network defence and offensive cyberwarfare tools.
5. *Skill and talent gap*: The Quess report brings out that less than 5 per cent of defence technology workforce is AI/cyber specialists.[66] This implies a huge talent gap.
6. *Procurement/acquisition gaps*: Existing models (Make I, Make II, SP) have accelerated indigenisation but lag warfighter needs with respect to faster development times. Critical gaps include long lead times to field cutting-edge technology and limited use of agile contracting. Operational user needs field-friendly drones, custom robotics, and so on, which often get stalled in bureaucracy. Introducing parallel acquisition tracks, like the iDEX 'path to procurement', is helpful but needs scaling up.[67]

7. *Infrastructure gaps*: Testing ranges for UAVs, swarms and lasers are limited.

International Trends and Comparative Gap Analysis

Defence technology is moving to a networked, software-defined and autonomous warfare model integrating AI, sensors, autonomous systems, electronic warfare, cyber, space, quantum technologies, advanced materials, directed energy and resilient communications. The Major international trend is the convergence of multiple technologies into military systems and operational ecosystems. The emerging defence architecture's representation is depicted as:[68]

Sensors → Data → AI → Decision → Resilient Network → Autonomous/Precision Effector

Traditional weapon platforms of the three Services become nodes within a larger combat ecosystem.

United States

The US defence technology ecosystem integrates advanced technologies with large-scale investment in defence R&D, operational trials and procurement. Their approach is to move technology rapidly from research to acquisition. Salient features include:[69]

- DARPA ecosystem for global technological leadership in AI, semiconductors, autonomy and defence innovation;
- Deep integration of private tech giants: Lockheed Martin, Palantir Technologies, Google.
- Advanced joint all-domain (Land + Air + Maritime + Space + Cyber) command & control (JADC2) data and decision frameworks
- Mature cyber warfare capabilities: US Cyber Command.

China

China's defence technology ecosystem combines State-directed R&D, civilian technology ecosystem, military requirements and industrial scaling up. Further, China has a very large commercial technology base and the civilian-industrial ecosystem can easily be converted into defence capability at scale. Salient features include:[70]

- State-driven civil-military fusion strategy

- Rapid prototyping and scaling: AI, drones and quantum communication
- Strong manufacturing base for mass production: unmanned systems

Europe

Europe's defence technology ecosystem is an association of EU institutions, NATO members, national defence industries and multinational programmes. Salient features include:

- European Defence Fund (EDF) emphasises collaborative R&D.[71]
- Future Combat Air System (FCAS):[72] A multinational programme that involves France, Germany and Spain developing a next-generation fighter with intended architecture: Next-generation fighter, Remote Carriers (loyal wingmen), Combat Cloud (networked C2 system), Sensors and AI.
- Global Combat Air Programme (GCAP): Another multinational programme that involves UK, Italy and Japan also emphasis on an integrated combat system than merely a new aircraft.

Israel

Israel due to its need to maintain a high operational tempo has developed a defence technology ecosystem that has the following salient features:[73]

- Strong R&D
- Startup-driven defence innovation
- Rapid field trials
- Close military–industry interaction.

India's Position

India is transitioning from platform acquisition defence technology model to an indigenous R&D, manufacturing, startup and dual-use technology ecosystem. It has created numerous mechanisms to connect defence users, R&D and industry.

Recommendations

India's envisaged military transformation and effectiveness to sustain future conflicts will depend on its ability to: integrate advanced disruptive technologies; accelerate product innovations; reform military doctrines, structures, human resource, procurement processes and institutions; accelerate indigenous hardware and software capabilities in military's digitised architecture; strengthen cyber and EW, space and maritime domains; and

finally, secure supply chains, logistics transformation and industrial self-reliance.

The characteristic shift in warfare towards MDO, AI-enabled decision-making, employment of autonomous systems, cyber and EW, precision and space-based assets necessitates strengthening the capabilities pertaining to India's defence technology ecosystem, expediting the implementation of its military reforms, associated training of the human resource, consolidation of its strategic resilience, undertaking industrial and logistics reforms and finally, good governance and accountability. India's military transformation will, thus, require a whole-of-government, armed forces, industry and academia approach to achieve a coordinated national defence technology and capability development framework.

Defence Technology Ecosystem Capability Enhancement

Defence Technology Commission (DTC)

A national-level DTC, under the chairmanship of the NSA or the Raksha Mantri, is quintessential to achieve a unified and non-fragmented approach. The DTC could function under the National Security Council and have representation from associated stakeholders, such as the MoD, the DRDO, the DDP, Headquarters Integrated Defence Staff, the ISRO, the Indian National Space Promotion and Authorisation Centre (IN-SPACe), the ANRF, the Ministry of Electronics and Information Technology (MeitY), the Ministry of Education, defence industry, start-up ecosystem and academia. The DTC could formulate a Defence Technology Strategy (DTS) every five years, prioritise defence technology missions and monitor their implementation through annual reviews.

National Defence Technology Mission

While national technology missions are focused, time-bound government initiatives designed to achieve technological self-reliance and enunciated for few emerging disruptive technologies, there is a need to realign defence-centric projects with the defined national technology missions, such as military AI, quantum defence, military robotics, hypersonics, defence semiconductor and directed-energy missions. Each military/defence mission could move beyond the erstwhile DRDO/DPSU-led development/production model to a whole-of-nation innovation model.

These military/defence missions could have one, two or more lead agencies in the form of the DRDO, DPSUs, the ISRO, the MeitY and

industry prime. There would also be associated supporting organisations, such as the academia—the IITs, the IISc and so on—the industry, AI start-ups and services. Each defence technology mission outlay should have defined TRLs, milestones, budgets and an independent review board. Eventually, technology development at the national level would become mission-driven rather than organisation-driven.

Defence R&D Funding

The annual budget allocations have had inherent criticisms of inadequacy of research funds, delayed disbursement and procedural requirements, such as timely submission of claims under various schemes/grants-in-aid and audit and statutory requirements. There is, thus, a need to shift to a portfolio-based model for funding purposes, for instance, basic research, applied research, long-term strategic research, prototype development, user trials or rapid innovation and product integration.

Further, private sector participation could be increased by introducing more competitive grants and venture funding. There is a need to increase the defence budget from present-day 2 per cent to 3 per cent of the GDP by 2030; and defence R&D spending should be increased from existing 6–7 per cent to 8–10 per cent of the defence budget. Higher funding should prioritise advanced materials and alloys, AI, autonomous combat and logistics systems, robotics, offensive and defensive cyber, directed-energy weapons, hypersonics, quantum technologies and space-based systems.

Defence–Academia–Industry Collaboration

In India, academia–industry–military collaboration was abysmal till a decade back, as the civilian academia had minimal direct defence collaboration. Recent DRDO academic chairs and shared lab facilities or research centres are bridging this gap. Academia is being increasingly engaged via new institutes, thematic quantum hubs and collaborative programmes. Even the University Grants Commission and the All India Council for Technical Education are now offering structured defence technology curricula for BTech/MTech students in defence technology (engineering stream).

The DRDO–industry–academia CoEs, or technology clusters, have been established across premier institutes, like IIT Kanpur, IIT Bombay and the IISc. These focus on cutting-edge research in hypersonic technology, AI, nanomaterials and advanced computing. The DRDO's new CoEs in AI, robotics and quantum also collaborate with the private sector. Thus, establishing of defence technology CoEs in the IITs, the IISc and major

universities is the way ahead. Each such CoE should be linked to one emerging technology area, for instance, AI, autonomous systems, quantum, cyber, advanced materials and alloys and directed energy. Defence officers could be embedded within these CoEs to define operational requirements. In this manner, defence investments at universities can be planned to boost relevant R&D.

Defence Technology Transition Acceleration

Most projects fail during TRL progression: Research Prototype Field Trial Limited Series Production Mass Production. This happens mostly between TRL 4 and TRL 7, that is, between laboratory success and operational induction. This critical gap is often called the 'valley of death' as research grants run out and technology progression is still early/risky to attract private venture capital or commercial funding. There is, thus, a need to adopt TRL-based management for technology and reduce this critical gap by creating dedicated transition teams to guide through this period of high cost of innovation by finding suitable sources for additional funding and solving any technology hurdles that may arise during TRL 4–7.

AI Adoption

There is a need to develop indigenous AI capabilities for each of the requirements of ISR fusion analytics, target recognition and analysis, battlefield decision-support systems, command-support systems, employment of autonomous combat systems/weapon systems, including swarms, management and optimisation of logistics and predictive maintenance analytics. India's AI Task Force and the Defence AI Council need to scale up AI for large-scale operational integration. This would need AI engineers making strong algorithms and tools, especially for NLP for multilingual intelligence, surveillance video analysis and multitarget tracking. Future needs include automated threat recognition as 'AI for Maneuver and Fires' in battlefield AI;[74] AI-enabled decision aids for kill chains; logistics optimisation; and limited certified AI systems for command and control.

Secure defence-foundation models have to be first created, and then trained on classified military datasets in protected computing environments. For such defence-foundation large language model (LLM), data accuracy, authenticity and accountability will be paramount as data credibility and accuracy are mandatory. Initial defence-foundation LLM models could ingest old situation reports (SITREPS), intelligence reports (INTREPS), intelligence summaries (ISUMs) and selected open-source intelligence

(OSINT) to ascertain results. The final goal is to achieve 'true autonomy' (where systems will be acting with no human link). Currently, these nascent models are at the R&D stage. Doctrines do aim to reach such higher autonomy with autonomous ISR drones learning from missions[75] (for example, the US by 2035); and India must bridge this gap at the earliest.

Unattended Autonomous Warfare

Unattended warfare vehicles are military systems designed to perform combat operations (track and engage targets/launch precision strikes), ISR (real-time battlefield intelligence, monitor enemy movements and infiltrate hostile areas) and combat/logistical tasks (deployed to defuse landmines, IEDs and unexploded ordnance; transport supplies and ammunition; and evacuate wounded soldiers in inaccessible terrain) without putting the human operator at risk. These are remotely operated by teleoperation or are semi/fully autonomous using onboard sensors (high-resolution optical and thermal sensors) and AI-powered systems (which allow vehicles to navigate complex terrain/obstacles and follow pre-programmed waypoints).

India is investing in unattended aerial/ground/surface/underwater vehicles, including drones, drone swarms, loitering munitions and human–machine teaming. Smaller UAVs are being used, but fully autonomous swarms are still emerging. Aggressive autonomy (swarming drones, robotic combat vehicles) is being tested in exercises, but is experimental at TRL 3–5. India, today, needs to put concerted efforts in some critical areas where it is lagging, such as engine technology, high-end autonomy algorithms and stealth technology.

Robotics

Integration of robotics is required for autonomous combat and logistics vehicles. Semi-autonomous ground robots (for surveillance/IED disposal) are currently being used in limited roles. It is also essential to focus on future needs, such as border and maritime surveillance with drones/satellites, remote mine clearance and autonomous logistic convoys in left-wing extremism zones.

Reforming Military Capability

Theatre Commands Integration and Operationalisation

An Integrated Theatre Command (ITC) is a unified structure where assets from the army, the navy and the air force operate under a single

Commander for a specific geographical area. The geographical areas and envisaged headquarters of various ITCs are: Northern (headquartered in Lucknow); Western (headquartered in Jaipur); and Maritime (headquartered in Thiruvananthapuram). The ITCs will ensure better coordination, faster decision-making and improved combat effectiveness, while mitigating shortcomings of single-service operations and integrating emerging warfighting capabilities, such as cyber and space. This will require both retaining service expertise and integrating operational planning and execution. Implementation is envisaged as follows:

1. *Phase 1*: Joint logistics, joint ISR and joint communications.
2. *Phase 2*: Theatre planning and theatre intelligence.
3. *Phase 3*: Fully operational theatre commands.

The Chief of Defence Staff (CDS) has formally submitted the final proposal for the creation of Integrated Theatre Commands to Defence Minister Rajnath Singh, marking the completion of inter-service deliberations internally referred to as 'Operation Tiranga'.[76] The creation of needs to be expedited as the theatre command structure incorporates emerging domains of warfare. Each command will integrate capabilities related to cyber operations, space-based systems, and electronic warfare, alongside enhanced Intelligence, Surveillance, and Reconnaissance (ISR) frameworks that are so essential for undertaking MDO,

MDO Warfighting

The Joint Doctrine for Multi-Domain Operations, released in 2025, integrates land, air, maritime, cyber, space, electromagnetic spectrum and information operations. The joint MDO warfighting effectiveness necessitates the conduct of regular tri-service exercises focused on various aspects of cross-domain integration. Indeed, the success of future MDOs will depend on synchronised effects across all domains.

Command Decentralisation

As seen in recent conflicts the world over, there is a need to increase decentralisation, while empowering commanders through better situational awareness, AI-assisted planning and secure communications. By constituting tailored mission commands whenever needed, decision making could be faster and more adaptive.

War-gaming

Creating permanent centres for AI-enabled war-gaming, digital battlefield simulation, operational experimentation and technology demonstrations will surely help during war-gaming. The feedback of such regular experimentation could be very useful and would enable refinement of doctrines and procurement.

Defence Procurement Reforms

India's defence procurement is governed by Draft DAP 2026 and DPM 2025. These reforms focus on local IP ownership, compressing trial and cost-negotiation timelines and accelerating MDO capability induction through large-scale capital investments and localised tendering. To reduce procurement timelines, there is a need to adopt agile procurement, rapid acquisition, continuous capability upgrades and open architecture systems. These will enable shrinking technology cycles and shorten development and deployment times. Further, the approach of spiral development (used effectively in several advanced defence ecosystems) is recommended. This approach propagates: Prototype → Limited induction → User feedback → Incremental upgrades.

Accordingly, Indian design, development and manufacture projects should adopt spiral development rather than acquiring a perfect system after waiting for over 15–20 years. There is, thus, a need to introduce and promote spiral acquisition, modular procurement, open architecture systems, agile contracting and multi-year procurement plans. It is also necessary to set statutory timelines for major acquisition decisions and periodically expand the delegated financial powers for rapid procurement.

Digital Armed Forces

To expedite digitisation of the armed forces, there is a need to implement paperless operations, digital AI planning, digital twins, defence cloud-enabled command systems, digital logistics and predictive maintenance.

Data-centric Warfare

This will necessitate treating data as a strategic asset. For this, all data has to be credible in its accuracy, authenticity and accountability. Such data then has to reside in secure defence data centres (DCs), forming either a part of the defence cloud or on premise, for edge computing. Different types of defence DCs have to be developed, each having varied qualitative requirements.

Together, they will be responsible for providing captive compute for data fusion, real-time battlefield analytics and common real-time situational awareness operational picture.

To enable the use of all applications of emerging technologies for MDO, there will be a requirement of approximately 10 kilowatt (kW)–40 kW defence distributed edge data centres (EDCs) at forward formations (division and ahead), which will compute to look and strike deep, while approximately 200 kW–1,000 kW defence DCs are required at rear formations (corps level and rearwards). Defence DCs/EDCs should be indigenous and interconnected with existing optical fiber cable, radiofrequency and satellite communication backup. All data from acoustic sensors, cameras, night vision devices, drones, and so on must be fed from the LoC/LAC/International Border (IB) into the EDCs. Hierarchical access to data at all levels, with mandate, will have to be specified. The grid will also require to be provided redundancy against physical attack.

Indigenous Digitised Architecture for the Armed Forces

In order to achieve transformation for undertaking data-driven, network-centric multi-domain warfare in future, there is a need to develop an indigenous defence digital architecture. This architecture will comprise of all ingredients, starting from defence cloud infrastructure, secure military networks, including their component parts, secure AI-enabled battlefield and command decision-support system, integrated logistics optimisation systems, digital maintenance records for predictive analytics, common operational picture and adopting common data standards across the Services.

Indigenous Defence Hardware

India has been dependent on computer systems and network hardware from foreign suppliers, be it semiconductor chips, graphics processing units, network switching systems or hardware diagnostic tools. Indigenous chips will reduce dependence on imported chips by developing secure and trusted defence-grade semiconductor capability for use in avionics, EW, missile and radar systems and processors. There is also the need for indigenous sensors and network electronic components.

Indigenous Defence Software

India is dependent on foreign operating systems (such as Windows and Linux), web application firewalls, antivirus, firmwares, BIOS, software tools, updates, patches and so on. There is a need to promote secure indigenous

operating systems, mission software, AI frameworks, cloud infrastructure and cybersecurity tools to reduce foreign software dependence.

Transform Logistics

India's defence logistics involves seamless, end-to-end management of sensitive military goods, spare parts and maintenance, repair and overhaul services to support operations in most challenging operating terrains. India, to increase logistics efficiency, has outsourced commercial supply chains to private logistics providers, securely transporting components from manufactures to military bases. In addition, the country has forged operational readiness through reciprocal exchange of logistics agreement (RELOS) and bilateral pacts with major defence partners, including the US, Russia, Australia, Japan, France, Singapore and South Korea.

In order to make logistics more effective, there is need to accelerate the implementation of predictive maintenance using AI analytics; radiofrequency identification (RFID) of all store items for Internet of Things (IoT)-enabled AI inventory management; additive manufacturing for selected spares, especially at forward locations; blockchain for supply chain traceability wherever appropriate; and autonomous logistics in suitable environments.

Human Capital

Talent Gap—Quess Report

As mentioned earlier, the Quess report has brought out that less than 5 per cent of defence technology workforce consists of AI/cyber specialists.[77] This implies that there is a huge talent gap. To plug this gap, the following is required:

1. Domain specialists: AI engineers, data scientists, quantum physicists, robotics experts, cyber operators and specialists.
2. Defence technology universities with specific defence technology curricula.
3. Lateral entry of tech experts into the armed forces.

Reform Military Education

It is imperative to modernise curricula at the National Defence Academy (NDA), Cadets Training Wings (CTWs), Indian Military Academy (IMA), Indian Naval Academy (INA), Air Force Academy (AFA), Defence Services Staff College (DSSC), College of Defence Management (CDM) and National

Defence College (NDC), to include AI, cyberwarfare, data analytics, robotics, space operations, systems engineering and technology management.

Specialist Career Streams
An important consideration is developing dedicated cadres for AI, cyber, data science, EW, robotics, space and so on. Also, enabling career pathways and lateral induction of technical experts where required is crucial.

Civil–Military Integration
Increasing cross-postings between the armed forces, the DRDO, the DDP, the MoD, the DPSUs, industry and academia will be helpful. This will promote collaboration in planning and project execution.

Strategic Capability

Critical Technologies
Developing national programmes for advanced materials, battery technologies, precision guidance, propulsion, rare earth processing, semiconductors and secure communications is necessary.

Secure Supply Chains
It is essential to diversify sourcing and build/maintain strategic reserves for rare earth elements, critical minerals, energetic materials, advanced material alloys, electronics and propellants which are required for building defence products.

Space Capability
There is a need to expand space-based surveillance satellites to improve threat detection and cue defensive systems, along with HAPS and stratospheric airships for ISR. This expansion is also necessary for ensuring continuous connectivity, besides secure quantum communication. Thus, there is a requirement to strengthen the Defence Space Agency, space launch capability, military satellite constellations, space situational awareness and space-based ISR. Further, increased cooperation between the ISRO, the IN-SPACe and private industry is essential.

Cyber Resilience
Future wars will begin in cyberspace. Hence, there is a need to create integrated capabilities for offensive cyber, defensive cyber, electronic attack, electronic

protection and electromagnetic spectrum operations. It is also necessary to expand AI-assisted cyber defence, cyber workforce development, Defence Cyber Agency, national cyber ranges and offensive cyber capability. To achieve cyber resilience, conduct of regular offensive and defensive exercises is a must. Today, AI-driven cybersecurity tools and quantum crypto analysis are rapidly evolving, and this will create new threats. Hence, the country has to prepare for future needs, including protecting critical infrastructure and command nets, AI-enabled EW to counter enemy drones/jammers and cyber forensics and deception.

Quantum Technology

Quantum developments in India are at a low TRL stage—and therefore, India has few fielded systems—and the quantum industrial base is limited. Currently, most quantum technology areas are at TRL 2–4, that is, laboratory and few prototypes. Thus, experiments in this field are likely only by 2030. A gap exists in quantum materials; intelligence from quantum sensors (magnetometers, clocks); secure communication from quantum (QKD demonstrated in lab awaits infrastructure for wider deployment; further, full satellite QKD not expected before 2030); high-precision quantum navigation independent of GPS; and scaling up of quantum computing from 50 qubits to large-scale 1,000 qubits by 2050. For all this to happen, research for quantum materials needs to be assigned to the academia, with focus areas being large-scale quantum computing, quantum communication and PQC.

The 'Military Quantum Mission Policy Framework' has been enunciated recently to integrate quantum sensing, communication, computing and materials into the armed forces.[78] This framework has been aligned with India's National Quantum Mission. The new quantum mission roadmap should plan to bridge these with lab demonstrators and partnerships. There is a need to prioritise investing in quantum technologies, particularly in sensing, navigation, communication, computing and encryption. These technologies will have strategic implications in coming decades. Operationalising quantum pilots for sensing and navigation while deploying quantum communication pilots, as well as pursuing scalable quantum computers, an integrated space-cum-ground quantum network and 6G (as being pushed by China), should be considered as priority hereafter.

Grey-Zone Activities

With increasing threats to national security due to grey-zone activities, there is a need to create an integrated national framework that combines intelligence,

information operations, influence operations, diplomatic engagement, economic coercion/measures, maritime coercion, cyber capabilities and border incursion management. Concurrently, to improve response, fusion centres for real-time coordination must be established.

Maritime Technology Leadership

Expanding indigenous capabilities in underwater surveillance, autonomous maritime systems, long-range precision strike, ASW and naval AI is vital for India's defence architecture.

Industrial Self-reliance

Defence Manufacturing

Private sector, often funded through government co-financing, undertakes innovation and system integration, and also invests in R&D centres. In recent times, a culture of co-development has emerged, with industry lobbies, such as CII and FICCI Defence, advocating further policy clarity, easier licensing and acquisition of IP from start-ups, which need to be considered and resolved.

DPSUs

These execute production and scale up large projects. The DPSUs are now co-owners of DIO, partner incubators and are increasingly teaming up with private SMEs under the SP model (such as the HAL's chopper programme with partners). The DPSUs are expected to boost joint ventures and enable technology absorption.

Increase Private Sector Participation

This can be achieved by addressing all their pain points pertaining to long-term procurement visibility, simplified licensing, export facilitation, joint ventures, technology transfer, outcome-based contracts and level playing competition with public sector capabilities.

Innovation Reforms

Defence Innovation Culture

There is a need to encourage calculated risk-taking by accepting iterative development; fund high-risk, high-reward research; provide sustained

support for start-ups; and encourage collaboration between users, scientists and industry. Innovation should be rewarded across the defence ecosystem.

Promote Start-ups

As mentioned earlier, various incubators, like NSRCEL–IISc and i-Hub–DRDO in the IITs, and industry bodies are now mentoring start-ups. This kind of guidance needs to be further stimulated. Start-ups can also be promoted by expanding the iDEX challenges, the TDF and venture funding for dual-use technologies. A portion of the procurement budget should be reserved for innovative SMEs and start-ups.

Investors and Industry Funds

While private industry and Venture Capital/ Private Equity (VC/PE) interest in defence technology is growing, government policies, as sovereign co-investment and tax incentives will remain enablers. Thus, the discipline with more than US$ 100M in deep-tech will need even higher budgets.

Infrastructure

There is a requirement for more dual-use test ranges, simulation laboratories and AI compute infrastructure. In addition, testing ranges for UAVs, swarms and lasers are also limited. The DRDO is establishing dedicated testbeds to address this need for specialised testing infrastructure. Apart from this, cyber range platforms and joint war-gaming with allies (AI test labs) are the emerging needs which will have to be addressed.

Defence Innovation Clusters

In addition to the two DICs in Uttar Pradesh and Tamil Nadu and numerous iDEX incubators to drive deep-tech, India needs to advance its defence ecosystem through state-based regional defence manufacturing and innovation clusters. The aim would be to decentralise production and build specialised military manufacturing ecosystems. Each such cluster could specialise in selected technology domains and integrate universities, start-ups, testing facilities, military users and manufacturing ecosystem. Some planning in this regard has begun and needs to be pursued for early fructification. Possible clusters identified are as follows:[79]

- Karnataka, supported by IISc Bengaluru, will lead policy, governance and institutional architecture.
- Telangana, supported by IIT Hyderabad and IIT Delhi, will spearhead market access, demand visibility and defence exports.

- Maharashtra (Pune), supported by IIT Bombay and IIT Indore, will focus on MSMEs and start-ups.
- Tamil Nadu, supported by IIT Chennai and IIT Tirupati, will lead defence industrial infrastructure and common facilities.
- Uttar Pradesh (Lucknow), supported by IIT Kanpur, Banaras Hindu University and IIT Roorkee, will oversee testing, certification, quality and standards.
- Assam, supported by IIT Guwahati, will coordinate the cluster for north-eastern and border states.
- Gujarat (Ahmedabad), supported by IIT Gandhinagar and IIT Bhubaneshwar, will focus on skill development and industry–academia linkages.

Global Partnerships and Alliances

There is a need to further deepen cooperation by tapping the strengths of the US (AI, cyber, ISR systems), the EU (quantum, advanced manufacturing) and Israel (drones, missile defence). Access to trusted technology coalitions, like PAX Silica, will also help avoid supply chain risks.[80]

Defence Export-oriented Industry

The government's aim is to position India among the world's leading defence exporters by supporting private industry, simplifying export approvals, promoting co-development and strengthening after-sales support. To enhance global marketing, there is a need to establish a Defence Export Promotion Authority to identify export markets, assist in certification, support financing, provide after-sales support, coordinate government-to-government initiatives and align product development with both domestic and export requirements.

Governance and Accountability

Introduce Capability-based Planning

It is essential to shift from platform-centric planning to capability-based planning by defining operational effects (for instance, persistent surveillance, long-range precision strike and resilient communications), and then select the mix of systems needed to deliver them.

Develop National Defence Technology Roadmaps

Preparing a classified and public five-year roadmap for advanced materials, AI, cyber, directed energy, hypersonics, quantum technologies, robotics,

unattended autonomous systems and space is important, which must be reviewed and updated every five years. Also, linking technology priorities with force development and budgeting is a must.

Establish Independent Programme Reviews

There is a need to create external review panels comprising retired military specialists, scientists, industry experts and academic specialists. Assessing projects on schedule, cost, technical maturity and operational relevance, with recommendations feeding into funding decisions, is also essential.

Introduce Performance Metrics

Progress should be measured using key performance indicators. Besides, senior leadership reviews need to be linked to the following measurable outcomes:

1. percentage of indigenous content in major systems;
2. TRL progression;
3. average acquisition cycle time;
4. share of procurement from Indian industry and MSMEs;
5. defence exports;
6. number of technologies successfully inducted into service; and
7. joint operational readiness metrics.

Whole-of-Government National Security

Another important aspect is enhancing coordination among the armed forces, the DRDO, the ISRO, the MoD, the MeitY, the Ministry of Home Affairs, the NSCS, industry and academia.

Political and Institutional Commitment

There is requirement for long-term policy stability through bipartisan support for critical defence programmes, predictable funding and regular parliamentary oversight. Institutional continuity is essential because many transformational capabilities require development cycles of 10–20 years.

Conclusion

The success of India's defence transformation will depend not on individual technologies or isolated reforms, but on institutional integration, time-bound disciplined execution and sustained investment. Technology, doctrine, procurement, human capital, industrial policy and strategic autarchy will have to evolve together. A coordinated implementation model—linking

government ministries, the armed forces, research institutions, academia, public sector enterprises, private industry, MSMEs and start-ups, through clearly defined responsibilities, measurable milestones and periodic review—could offer the most credible path to building a technologically advanced, self-reliant, fully integrated and operationally effective military capable of meeting India's warfighting and security challenges through 2050 and beyond.

Notes

1. James Burd, 'Decoding Modern Warfare: The Transformation of Battlefields in the 21st Century', *Military Conflict*, 3 January 2024, available at https://www.militaryconflict.org/decoding-modern-warfare-the-transformation-of-battlefields-in-the-21st-century/, accessed on 16 March 2026.
2. Patricia Miller, 'The Impact of Artificial Intelligence on Modern Military Operations', *Value The Markets*, 15 April 2026, available at https://www.valuethemarkets.com/cryptocurrency/news/the-impact-of-artificial-intelligence-on-modern-military-operation, accessed on 16 April 2026.
3. Kartik Bommakanti (ed.), 'A Decade of Defence Reforms under Modi', ORF Special Report No. 230, Observer Research Foundation, 15 July 2024, available at https://www.orfonline.org/research/a-decade-of-defence-reforms-under-modi, accessed on 16 March 2026.
4. Ranjit Ghosh, 'Indian Research and Development Ecosystem for Self-Reliance', *Journal of Defence Studies*, Vol. 18, No. 3, 2024, pp. 11–43, available at https://idsa.in/publisher/journal-of-defence-studies/indian-research-and-development-ecosystem-for-self-reliance, accessed on 15 March 2026.
5. 'Enhancement of Capacity of Defence Forces', Press Information Bureau, Ministry of Defence, Government of India, 4 February 2022, available at https://www.pib.gov.in/PressReleseDetailm.aspx?PRID=1795536&reg=3&lang=2, accessed on 16 March 2026.
6. 'Technology Perspective Capability Roadmap: TPCR 2025', Department of Defence Production, Ministry of Defence, Government of India, 4 September 2025, available at https://srijandefence.gov.in/FINAL-TPCR-2025_0.pdf, accessed on 16 March 2026.
7. Jose K. George, 'Is India's Biggest Military Reform Nearing Reality? Theatre Command Plan Takes Definite Shape with IAF in Lead on Western Front', *The Week*, 9 April 2026, available at https://www.theweek.in/news/defence/2026/04/09/is-indias-biggest-military-reform-nearing-reality-theatre-command-plan-takes-definite-shape-with-iaf-in-lead-on-western-front.html, accessed on 16 March 2026.
8. Shailesh Kumar, 'Indian Army Prepares Blueprint for "Year of Reforms"', *National Defence*, 8 January 2025, available at https://nationaldefence.in/news/indian-army-

prepares-blueprint-for-year-of-reforms/#google_vignette, accessed on 16 March 2026.

9. Ashok Patel, 'How an Increased Policy Focus on R&D can Spur the Indian Medtech Sector towards Self-reliance', *The Economic Times*, 11 April 2022, available at https://health.economictimes.indiatimes.com/news/medical-devices/how-an-increased-policy-focus-on-rd-can-truly-spur-the-indian-medtech-sector-towards-self-reliance/90773595, accessed on 16 March 2026.
10. Samir Patil, 'Strengthening India's Defense R&D Ecosystem', Gateway House, Indian Council on Global Relations, 27 July 2021, available at https://www.gatewayhouse.in/strengthening-indias-defense-rd-ecosystem/, accessed on 17 March 2026.
11. Ravindra Vikram Singh, 'R&D Ecosystem in India: Where We Stand', LinkedIn, 24 March 2023, available at https://www.linkedin.com/pulse/rd-ecosystem-india-where-we-stand-frsc-fics-macs/le, accessed on 17 March 2026.
12. 'R&D: Path to Self-reliant India', *Civils Daily*, 27 May 2020, available at https://www.civilsdaily.com/news/rd-path-to-self-reliant-india/, accessed on 17 March 2026.
13. 'Schemes/Programmes', Department of Science & Technology, Government of India, available at https://dst.gov.in/schemes-programmes, accessed on 18 March 2026.
14. 'INSPIRE Scheme', Department of Science & Technology, Government of India, available at https://dst.gov.in/inspire-scheme-innovation-science-pursuit-inspired-research, accessed on 18 March 2026.
15. 'iDEX Initiative Powers India's Defence Start-up Boom—$344 Million Innovation Push Unveiled', *Indian Masterminds*, 31 October 2025, available at https://indianmasterminds.com/news/idex-initiative-key-driver-defence-innovations-india-156197/, accessed on 18 March 2026.
16. Atharva Salunke, 'Technology Development Fund (TDF) Scheme (2025)', Impact and Policy Research Institute (IMPRI), 15 October 2025, available at https://www.impriindia.com/insights/policy-update/technology-development-fund/, accessed on 18 March 2026.
17. Ranjit Ghosh, 'Indian Research and Development Ecosystem for Self-Reliance', n. 4
18. 'Raksha Mantri Shri Rajnath Singh Unveils Defence Acquisition Procedure–2020', Press Information Bureau, Ministry of Defence, Government of India, 28 September 2020, available at https://www.pib.gov.in/pressreleasepage.aspx?prid=1659746&reg=3&lang=2, accessed on 19 March 2026.
19. 'Record 75 per cent of Defence Capital Procurement Budget Earmarked for Domestic Industry in FY 2023-24, Announces Raksha Mantri at 14th Aero India', Press Information Bureau, Ministry of Defence, Government of India, 15 February 2023, available at https://www.pib.gov.in/PressReleasePage.aspx?PRID=1899388&reg=48&lang=2, accessed on 19 March 2026.

20. 'Defence Procurement Manual (DPM) 2025', *Insight IAS*, 15 September 2025, available at https://www.insightsonindia.com/2025/09/15/defence-procurement-manual-dpm-2025/, accessed on 19 March 2026.
21. 'Atmanirbhar Bharat in Defence: 1.27 Lakh Crore in Production, 21,083 Crore in Exports', Press Information Bureau, Ministry of Defence, Government of India, 1 February 2025, available at https://www.pib.gov.in/PressReleasePage.aspx?PRID=2098431&reg=3&lang=2, accessed on 19 March 2026.
22. 'Technology Perspective Capability Roadmap: TPCR 2025', n. 6.
23. 'India's Joint Doctrine for Multi-Domain Operations: A Whole-of-Nation Framework', United Services Institution of India (USI), 27 August 2025, available at https://www.usiofindia.org/pdf/file_68c3c9dd2b33e.pdf, accessed on 19 March 2026.
24. 'National Technology Readiness Assessment Framework', Office of Principal Scientific Adviser to the Government of India, 17 December 2025, available at https://psa.gov.in/CMS/web/sites/default/files/publication/National%20Technology%20Readiness%20Assessment%20Framework_Final.pdf, accessed on 20 March 2026.
25. 'DRDO and IIT Delhi Scientists Demonstrate Quantum Key Distribution between Two Cities 100 Kilometres Apart', Press Information Bureau, Ministry of Defence, Government of India, 23 February 2022, available at https://www.pib.gov.in/PressReleasePage.aspx?PRID=1800648&reg=3&lang=2, accessed on 21 March 2026.
26. 'ISRO Makes Breakthrough Demonstration of Free-Space Quantum Key Distribution (QKD) Over 300 m', Indian Space Research Organisation (ISRO), Government of India, 22 March 2021, available at https://www.isro.gov.in/Quantum%20Key%20Distribution%20(QKD).html, accessed on 21 March 2026.
27. R. Anil Kumar, 'Artificial Intelligence (AI) in Indian Defence: Indian Defence Companies Harness AI to Transform Modern Warfare', *India Strategic*, 11 September 2025, available at https://www.indiastrategic.in/artificial-intelligence-ai-in-indian-defence/, accessed on 22 March 2026.
28. Manav Rastogi, 'Indian Army Deploys 100 Robotic Mules to High Altitude Areas, Also Considering Logistics Drones & -40°C Tents', *Defence.in*, 24 September 2024, available at https://defence.in/threads/indian-army-deploys-100-robotic-mules-to-high-altitude-areas-also-considering-logistics-drones-40-c-tents.10155/#google_vignette, accessed on 23 March 2026.
29. 'India's ALFA-S Drone Swarm: AI-Powered Strike Revolution', *Indian Defence News*, 21 May 2026, available at https://www.indiandefensenews.in/2026/05/indias-alfa-s-drone-swarm-ai-powered.html, accessed on 31 May 2026.
30. 'DRDO Exploring ASTRA MK-III with Emphasis on Advanced AI-driven Guidance and IFF Capabilities', *Indian Defence News*, 29 October 2025, available at https://www.indiandefensenews.in/2025/10/update-drdo-exploring-astra-mkiii-with.html, accessed on 24 March 2026.

31. 'Satellite Navigation Services', ISRO, Government of India, available at https://www.isro.gov.in/SatelliteNavigationServices.html, accessed on 24 March 2026.
32. 'Evolution of the AI Ecosystem in India: The Way Forward', in Economic Survey 2025–226, Ministry of Finance, Government of India, January 2026, Ch. 14, available at https://www.indiabudget.gov.in/economicsurvey/doc/eschapter/echap14.pdf, accessed on 24 March 2026.
33. Vitaliy Goncharuk, 'Chasing True AI Autonomy: From Legacy Mindsets to Battlefield Dominance', *War on the Rocks*, 15 December 2025, available at https://warontherocks.com/chasing-true-ai-autonomy-from-legacy-mindsets-to-battlefield-dominance/#:~:text=And%20unless%20the%20United%20States,intensive%20environments, accessed on 24 March 2026.
34. Michal Krelina and Denis Dúbravčík, 'Quantum Technology for Defence: What to Expect for the Air and Space Domains', Joint Air Power Competence Centre, February 2023, available at https://www.japcc.org/articles/quantum-technology-for-defence/#:~:text=It%20is%20important%20to%20stress,realistic%20expectation%20for%20fielded%20QT, accessed on 25 March 2026.
35. 'National Quantum Mission (NQM)', Department of Science & Technology, Government of India, available at https://dst.gov.in/national-quantum-mission-nqm#:~:text=The%20Mission%20objectives%20include%20developing,the%20deliverables%20of%20the%20Mission, accessed on 26 March 2026.
36. 'Post-Quantum Cryptography PQC- Migration to PQC', NIST Computer Security Research Center (CSRC), 12 November 2024, available at https://csrc.nist.gov/projects/post-quantum-cr yptography, accessed on 26 March 2026.
37. 'CDS Releases Military Quantum Mission Policy Framework', Press Information Bureau, Ministry of Defence, Government of India, 22 January 2026, available at https://www.pib.gov.in/PressReleasePage.aspx?PRID=2217374&reg=3&lang=2, accessed on 26 March 2026.
38. 'Defence Robotics in India: Grounded Assessment of DRDO, Boston Dynamics Spot, and Unmanned Ground Systems', *Robotwale*, 22 August 2026, available at https://www.robotwale.com/article/defence-robotics-drdo-spot-ugs, accessed on 23 March 2026.
39. Ibid.
40. Sebastien Roblin, '2025 Proved the Case for Drone Defense', Inside Unmanned Systems, 12 January 2026, available at https://insideunmannedsystems.com/2025-proved-the-case-for-drone-defense/#:~:text=While%20sustaining%20development%20of%20larger,acquire%20200%2C000%20more%20in%202027, accessed on 26 March 2026.
41. 'India's Strategic Pivot: India Seeks Engine Tech Autonomy after TEJAS Delays, Eyes Pact with Rolls-Royce or Safran', *Indian Defence News*, 11 July 2025, available at https://www.indiandefensenews.in/2025/07/indias-strategic-pivot-india-seeks.html, accessed on 26 March 2026.

42. Joe Devanny and Arthur P.B. Laudrain, 'Interpreting India's Cyber Statecraft', Carnegie Endowment for International Peace, 27 March 2025, available at https://carnegieendowment.org/research/2025/03/interpreting-indias-cyber-statecraft , accessed on 27 March 2026.
43. R. Anil Kumar, 'India's Strategic Expansion in Military Space: ISRO's Satellite Initiative and the Emerging Defence Space Doctrine', *India Strategic*, 13 April 2025, available at https://www.indiastrategic.in/indias-strategic-expansion-in-military-space/, accessed on 27 March 2026.
44. '16,000 MSMEs Contributing to Defence Sector's Growth: Mandaviya', *The Hindu BusinessLine*, 18 December 2025, available at https://www.thehindubusinessline.com/news/16000-msmes-contributing-to-defence-sectors-growth-mandaviya/article70411969.ece, accessed on 27 March 2026.
45. Mohammad Haris, '"Nearly 1,000 New Defence Startups Formed in Past 5–6 Years": PM Modi', *News18*, 28 October 2024, available at https://www.news18.com/business/nearly-1000-new-defence-startups-formed-in-past-5-6-years-pm-modi-9101417.html, accessed on 27 March 2026.
46. 'Parliament Passes the Anusandhan National Research Foundation (NRF) Bill, 2023 with the Rajya Sabha Adopting the Bill by a Voice Vote', Press Information Bureau, Ministry of Defence, Government of India, 9 August 2023, available at https://www.pib.gov.in/PressReleaseIframePage.aspx?PRID=1947230&reg=3&lang=2, accessed on 27 March 2026.
47. Ibid.
48. Ben Adler, 'India's Defence Tech Sector Sees Record $247M Funding Surge in 2025', *Defence Innovation Review*, 29 January 2026, available at https://defenceinnovationreview.com/2026/01/29/indias-defence-tech-sector-sees-record-247m-funding-surge-in-2025/, accessed on 27 March 2026.
49. 'Shastra VC Raises $100 Million to Back AI, Deeptech and Defence Startups in India', *Know Startup*, 22 May 2026, available at https://knowstartup.com/news/shastra-vc-raises-100-million-ai-deeptech-defence-startups-india-2026/, accessed on 25 May 2026.
50. 'Demand for Grants 2026-27 Analysis: Defence', PRS Legislative Research,17 February 2026, available at https://prsindia.org/budgets/parliament/demand-for-grants-2026-27-analysis-defence, accessed on 25 May 2026.
51. 'A Record Over Rs 6.81 lakh Crore Allocated in Union Budget 2025–26 for MoD, an Increase of 9.53% from Current Financial Year', Press Information Bureau, Ministry of Defence, Government of India, 1 February 2025, available at https://www.pib.gov.in/PressReleasePage.aspx?PRID=2098485&reg=3&lang=2, accessed on 28 March 2026.
52. 'National Quantum Mission (NQM)', n. 33.
53. Rajan Kochar, 'Defence Sector at an Inflection Point: From Import Dependence to Strategic Autonomy', *ET Government*, 21 February 2026, available at https://government.economictimes.indiatimes.com/blog/indias-defence-transformation-

from-import-dependence-to-strategic-autonomy/128638769#:~:text=Defence%20Startups%3A%20Embedding%20AI%20into,planning%20into%20its%20ISR%20UAVs, accessed on 28 March 2026.

54. 'National Quantum Mission: India's Quantum Leap—Unleashing the Power of Quantum Technology and Creating Jobs of Tomorrow', Press Information Bureau, Ministry of Science and Technology, Government of India, 17 March 2025, available at https://www.pib.gov.in/PressReleasePage.aspx?PRID=2111953&reg=3&lang=2, accessed on 27 March 2026.
55. 'iDEX Schemes and Services', Department of Defence Production, Ministry of Defence, Government of India, available at https://www.ddpmod.gov.in/offerings/schemes-and-services/idex#:~:text=Scheme%20for%20iDEX,SPARK%20Framework, accessed on 28 March 2025.
56. 'Research Development and Innovation Fund: Special Purpose Fund under ANRF', Anusandhan National Research Foundation (ANRF), available at https://rdifund.anrf.gov.in/, accessed on 28 March 2026.
57. Tatjana de Kerros, 'What the R&D Budget Proposal Says about the Future of War: The Pentagon's Research-and-Development Section Heralds Several Quiet, Monumental Shifts', *Defense One*, 1 July 2025, available at https://www.defenseone.com/ideas/2025/07/what-rd-budget-proposal-says-about-future-war/406467/#:~:text=If%20you%20want%20to%20understand,research%2C%20development%2C%20test%20and%20evaluation, accessed on 28 March 2026.
58. Matt Swayne, 'Pentagon Elevates Quantum Tech to Core of Future Battlefield Strategy National, Quantum Business', *The Quantum Insider*, 18 November 2025, available at https://thequantuminsider.com/2025/11/18/pentagon-elevates-quantum-tech-to-core-of-future-battlefield-strategy/#:~:text=The%20Pentagon%20is%20elevating%20quantum,Research%20and%20Engineering%2C%20Emil%20Michael, accessed on 28 March 2026.
59. 'Defense Advanced Research Projects Agency: Overview and Issues for Congress', CRS Report, 2 February 2018–19 August 2021, available at https://www.everycrsreport.com/reports/R45088.html, accessed on 28 March 2026.
60. Matt Swayne, 'China's New Five-Year Plan Specifically Targets Quantum Leadership and AI Expansion', *The Quantum Insider*, 5 March 2026, available at https://thequantuminsider.com/2026/03/05/chinas-new-five-year-plan-specifically-targets-quantum-leadership-and-ai-expansion/#:~:text=%2A%20China%E2%80%99s%20new%20five,tensions%20with%20the%20United%20States, accessed on 28 March 2026.
61. Paul Taylor, 'EDF 2.0: Keeping Research at the Heart of Europe's Defence Drive', European Policy Centre (EPC), 27 March 2026, available at https://www.epc.eu/publication/edf-20-keeping-research-at-the-heart-of-europes-defence-drive/#:~:text=With%20a%20budget%20of%20%E2%82%AC8,for%20collaborative%20capability%20development%20projects, accessed on 29 March 2026.

62. 'Emerging and Disruptive Technologies', North Atlantic Treaty Organization, available at https://www.nato.int/en/what-we-do/deterrence-and-defence/emerging-and-disruptive-technologies#:~:text=technological%20products%20to%20help%20address,sovereign%20venture%20capital%20fund, accessed on 29 March 2026.
63. 'Summary of the NATO Artificial Intelligence Strategy', North Atlantic Treaty Organization, 22 October 2021, available at https://www.nato.int/en/about-us/official-texts-and-resources/official-texts/2021/10/22/summary-of-the-nato-artificial-intelligence-strategy#:~:text=A,a%20NATO%20and%2For%20national%20level, accessed on 29 March 2026.
64. Dean Shmuel Elmas, 'Defense Ministry Orders Boost Israeli Startups', *The Jerusalem Post*, 22 January 2026, available at https://www.jpost.com/defense-and-tech/article-884168#:~:text=The%20last%20year%20was%20highly,MAFAT, accessed on 29 March 2026.
65. Samriddhi Srivastava, 'India Produces Engineers at Scale. So Why is Cybersecurity Talent Still Scarce?', *People Matters*, 16 March 2026, available at https://www.peoplematters.in/article/ai-and-emerging-tech/india-produces-engineers-at-scale-so-why-is-cybersecurity-talent-still-scarce-48804, accessed on 30 March 2026.
66. Neil Ghai, 'Defence Tech Reels from Scarce Advanced Engineering Talent: Report', *The Economic Times*, 2 December 2025, available at https://economictimes.indiatimes.com/news/defence/defence-tech-reels-from-scarce-advanced-engineering-talent-report/articleshow/125718257.cms?from=mdr, accessed on 31 March 2026.
67. 'iDEX Schemes and Services', n. 49.
68. Munish Bhatia and Pallavi, 'The Integration of Emerging Technologies in Defense: A Scientometric Overview', Engineering Applications of Artificial Intelligence, 1 January 2026,available at https://www.sciencedirect.com/science/article/abs/pii/S0952197625028532, accessed on 31 March 2026.
69. Aravind Sathishkumar, 'Inside America's New Defence Tech Ecosystem', ORF Middle East, 23 December 2025, available at https://orfme.org/research/inside-americas-new-defence-tech-ecosystem/, accessed on 31 March 2026.
70. Ben Adler, 'China's Dual-use Tech Fuels Rapid Military Innovation', *Defence Innovation Review*, 16 March 2026, available at https://defenceinnovationreview.com/2026/03/16/chinas-dual-use-tech-fuels-rapid-military-innovation/, accessed on 31 March 2026.
71. 'EDF Developing Tomorrow's Defence Capabilities', Defence Industry and Space-EU Defence Industry, available at https://defence-industry-space.ec.europa.eu/eu-defence-industry/european-defence-fund-edf-official-webpage-european-commission_en, accessed on 31 March 2026.
72 Muzaffer Ünsaldı, 'GCAP vs FCAS: Europe's Airpower Race', *Defence Agenda*, 12 June 2025, available at https://defenceagenda.com/gcap-fcas-6th-gen-fighter-jets, accessed on 31 August 2026.

73. 'Israel's Defense-tech Revolution: How MAFAT is Shaping the Evolution of Israeli Warfare', *The Jerusalem Post*, 26 December 2025, available at https://www.jpost.com/defense-and-tech/article-881440, accessed on 31 August 2026.
74. Tatjana de Kerros, 'What the R&D Budget Proposal Says About the Future of War', *Defense One*, 1 July 2025, available at https://www.defenseone.com/ideas/2025/07/what-rd-budget-proposal-says-about-future-war/406467/, accessed on 31 August 2026.
75. Vitaliy Goncharuk, 'Chasing True AI Autonomy: From Legacy Mindsets to Battlefield Dominance', *War on the Rocks*, 15 December 2025, available at https://warontherocks.com/chasing-true-ai-autonomy-from-legacy-mindsets-to-battlefield-dominance/, accessed on 31 August 2026.
76. 'CDS Anil Chauhan Submits Final Integrated Theatre Command Plan to Rajnath Singh; CCS Review Next', *The Defence News*, 27 April 2026, available at https://www.thedefensenews.com/CDS-Anil-Chauhan-Submits-Final-Integrated-Theatre-Command-Plan-to-Rajnath-Singh-CCS-Review-Next/, accessed on 25 September 2026.
77. 'Defence Tech Reels from Scarce Advanced Engineering Talent: Report', *The Economic Times*, 21 September 2026, available at https://economictimes.indiatimes.com/news/defence/defence-tech-reels-from-scarce-advanced-engineering-talent-report/printarticle/125718257.cms, accessed on 21 September 2026.
78. 'CDS Releases Military Quantum Mission Policy Framework', Press Information Bureau, Ministry of Defence, Government of India, 22 January 2026, available at https://www.pib.gov.in/PressReleasePage.aspx?PRID=2217374&reg=48&lang=2, accessed on 24 September 2026.
79. 'Centre Plans Seven Defence Manufacturing Clusters Backed by IITs', *News and Views of Alumni of IIT IIM Newsletter*, June 2026, available at https://iitiimsamvaad.com/2026/06/centre-plans-seven-defence-manufacturing-clusters-backed-by-iits/, accessed on 24 September 2026.
80. 'India Joins Pax Silica to Reduce Supply Chain Risks', *Chemical Industry Digest*, 23 February 2026, available at https://chemindigest.com/india-joins-pax-silica-to-reduce-supply-chain-risks/, accessed on 25 September 2026.