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From Surveillance to Precision Strikes: India's path to AI Driven - Indigenous Loitering Munitions and Drone Warfare

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Abstract

If the Nagorno-Karabakh War has popularised drone warfare, the Russia-Ukraine War has pushed the race for militarised drones and loitering munitions. Nations are now driving Artificial Intelligence (AI) in defence to further enhance their Drones with autonomous targeting, mission flexibility, intelligent decision-making and precision strikes. This paper studies usage of AI in Loitering Munitions and its implications. The paper further outlines AI research and deployment of Loitering Munitions in India, China and Pakistan. While China is advancing it's AI and autonomous platforms, Pakistan looks at targeted procurement methods. India, while balancing strategic mix of buy and build strategies, is making paradigm shift towards self-reliance and indigenisation. The paper concludes by addressing India's challenges in supply, manufacturing and technology and provides suggested measures to drive the advancements of AI and indigenisation of military drones, particularly loitering munitions to align with India's vision of Atmanirbharta and a global military power.

Keywords: AI in Drones, Loitering Munitions, Kamikaze Drones, Autonomous Drones, Drone Warfare, AI Drones, Autonomous UAVs, Artificial Intelligence, AI in Defence

Introduction

Much has been seen and said about the role of drones in modern warfare— from Turkey's conflicts, Russia-Ukraine war to the recent Operation Sindoor by India which has placed India at the forefront of modern war. The military drones are deployed not only for surveillance but also for recce, wait and execute precision strikes known as Loitering Munitions (LMs) and Kamikaze drones.

By 2018, USA, China and Turkey have garnered a market of 40 countries to supply military drones and by 2022, Turkey has dominated this market with 65% market share of global military drone industry by 2024 (InsideFPV, 2024).

Loitering munitions have experienced significant technological advancements by blending the accuracy of guided missiles and the versatility of UAVs with longer operational ranges,

sophisticated sensors, and enhanced targeting abilities. Such improvements have solidified the role of loitering munitions in contemporary armed forces, allowing for the precise engagement of both stationary and moving targets (McNeil, 2024).

A major factor driving growth of LMs is the increasing demand for precision strike capabilities in modern military operations. These systems offer the ability to engage high-value targets accurately while minimising collateral damage, thus making them indispensable for contemporary warfare strategies.

Technological advancements in unmanned systems have also significantly contributed to this market's expansion. Enhancements in artificial intelligence, sensor fusion, and autonomous navigation have greatly improved loitering munitions' effectiveness, thus making them a more attractive asset for defence forces worldwide.

Additionally, the expendable segment of loitering munitions is witnessing strong demand due to the systems' cost-effectiveness and operational efficiency, offering an affordable alternative for achieving strategic military objectives without compromising performance. (MarketsandMarkets, 2025).

Current Trends in Loitering Munitions

Commonly leveraged technologies and developments in combat drones include (InsideFPV, 2024):

- **Autonomous Decision-Making** to enable LMs independently detect and follow moving targets, alter their flight paths in real time, monitor and relay activity data and execute highly accurate strikes.
- **Low-Visibility Drones** with features such as noise-dampening technology, radar-absorbent materials, thermal masking, and day/night camouflage helps these drones to stay undetected during missions.
- **Collaborative Drone Swarm Technology** enables large groups of drones to operate as a cohesive unit. These drones exchange information and dynamically adjust their flight formations, allowing them to monitor extensive areas simultaneously, disrupt enemy radar systems and launch multi-directional attacks.

- **Modular Payload Capabilities,** that have swappable payload bays, hence, letting them adapt to various mission needs mid-flight. This flexibility allows a single drone to switch between surveillance, sensor, or combat equipments, serve multiple operational roles and reduce the variety of drones a team must deploy.
- **Extended Flight Endurance** addressing the limitation of flight time, new design improvements emphasise solar-powered platforms, like the Zephyr S, capable of remaining airborne for weeks, lightweight propulsion systems and enhanced battery technology for longer missions
- **Counter-Drone Technologies** use tools such as directed energy weapons, radio frequency jammers, signal interception devices, especially engineered drones that target and neutralise threats.
- **Global Positioning System (GPS)** navigation to identify predefined targets, loiter over extensive distances, and stay airborne over designated areas until a target is detected. GPS enables these UAVs to reach their objectives without direct human control. Additionally, it supports geo-fencing capabilities, which restrict drone operations to specified zones or mission boundaries addressing an essential feature for combat missions (InsideFPV, 2025).
- **Vision Systems** in LMs enable the detection of moving threats, recognition of human shapes, and locking onto heat sources such as engine blocks or weaponry. Often integrated with AI-driven image processing software, these systems allow rapid identification and classification to distinguish between tanks and trucks or combatants and civilians within milliseconds (InsideFPV, 2025).

Artificial intelligence (AI) Implementation

Use of AI in the defence industry has undergone remarkable development since its early days. Today, autonomous platforms can independently recognise terrain and identify targets, thus minimising dependence on satellite communications and increasing both operational efficiency and the accuracy of real-time targeting guidance. Although, drones have previously featured limited autonomous functions, recent breakthroughs indicate that AI-powered solutions now hold extraordinary promise for the sector (EM360, 2024).

The integration of AI-based intelligence, data analytics, voice recognition, advanced situational awareness, and automated technologies has significantly enhanced the capabilities of these systems (Maris Technologies, 2024).

AI serves as the control centre for LMs, empowering them to interpret their surroundings instantly, identify potential targets, and differentiate between allies and adversaries. This advanced decision-making capability is a key factor behind the effectiveness of today's loitering munitions (InsideFPV, 2025).

- **Autonomous Target Identification and Engagement:** Advanced AI algorithms process visual data from onboard cameras to recognise tanks, artillery pieces, radar stations, or even moving individuals. AI algorithms empower loitering munitions to independently identify, track, and prioritise targets such as enemy vehicles, artillery, radar installations, or personnel in real time. This capability minimises the need for constant human oversight and accelerates decision-making on the battlefield, resulting in faster, more precise strikes with reduced collateral damage. One such example is the Russian V2U loitering munition, that reportedly used AI for autonomous navigation and target engagement in recent conflicts (Howard, 2025).
- **Hover and Strike Logic**: With intelligent loitering functions, drones can patrol above a conflict zone and independently determine the optimal moment to attack (InsideFPV, 2025).
- **Real-Time Threat Assessment**: AI continually updates the drone's flight route, adapting to shifting enemy positions, changing weather, and fresh intelligence (InsideFPV, 2025).
- **Reduced Cost and Operator Input**: Once deployed, these drones require little or no direct control, decreasing the mental demands on military personnel (InsideFPV, 2025), (Verma, 2024).
- **Faster Kill Chain Compression**: AI dramatically shortens the time from target detection to engagement by automating threat analysis, route planning, and weapon deployment. In Ukraine's 2022-2025 conflict, AI-enabled "hunter-killer" drone teams coordinate surveillance drones with loitering munitions for rapid target acquisition and strike with minimal human input—compressing the kill chain from minutes to mere seconds (Lviv Herald, 2025).

- **Improved Mission Flexibility and Modularity:** AI supports adaptive mission profiles where a single loitering munition can switch targets or operational tactics based on evolving battlefield intelligence. Recent autonomous systems integrate modular payloads and advanced mission planning software, enhancing their applicability for diverse missions such as suppression of enemy air defences (SEAD), counter-battery fire, and precision strikes (openPR, 2025).
- **Real-Time Mission Management and Multi-Launch Systems**: Recent AI-powered systems, such as UVision USA' autonomous multi-launch loitering munition platform, manage multiple simultaneous munitions with real-time mission planning, target recognition, and threat prioritisation. Operators can deploy waves of drones autonomously while retaining overarching mission control, including abort capabilities mid-flight (FW Mag, 2024).

Nations are adopting AI strategies to capitalise on its natural benefits, including faster response time, cost efficiency, and enhanced protection against cyber threats. When it comes to incorporating AI into weapon systems, it is important to differentiate between two main types: automated and autonomous.

Automated systems execute fixed rule-based functions with limited adaptability and little to no ongoing human control, while autonomous systems are more complex, capable of independent decision-making, and adaptable, with varying degrees of human supervision depending on the system design (Francesco, 2024).

Table 1: Difference between Autonomous and Automated Integraton of AI in Drones

Automated Integration of AI	Autonomous Integration of AI
● Operate independently once deployed, following a predefined set of rules based on sensor inputs. ● Perform tasks in a predicted way without ongoing human control.	● Ability to identify and engage targets without manual involvement after launch. ● Perform multiple, complex functions and adapt changing environment dynamically.

● Examples include automated sentry guns, sensor driven munitions, and few anti-vehicle landmines. ● Typically handle specific, simpler functions with limited flexibility. ● May not qualify as fully automated if remotely piloted functions (e.g.navigation or takeoff) exist. ● Needs minimum or no real-time human intervention while performing an operation.	● Understand higher-level intent and decide actions from multiple alternatives to achieve objectives. ● Operate without human supervision or approval during missions. ● Often categorised by levels of human control: ○ **Human-in-the-Loop:** human command required for target engagement. ○ **Human-on-the-Loop:** operates with human oversight, allowing intervention. ○ **Human-out-of-the-Loop:** functions independently without human input. ● Advanced forms may incorporate AI for enhanced decision-making.

Source: Francesco, 2024

Country Wise Snapshot of AI Usage in Loitering Munitions and Other UAVs

The section covers an overview of loitering munitions and drone swarm capabilities and AI implementation and challenges faced by India, China and Pakistan.

China

China is working on its "Next Generation AI Development Plan", with close government and private collaboration to propel China to the forefront of global AI leadership by 2030. Backed by a defence budget of $250 billion, the initiative has already produced notable results—including a demonstration of swarming technology involving 1,000 coordinated drones, which highlights China's expertise in sophisticated autonomous systems.

The country's approach leverages the strengths of leading private companies such as Ziyan and DJI, whose technological innovations are closely aligned with national defence priorities. This seamless cooperation between state policies and private enterprise is positioning China as a major force in shaping the landscape of future autonomous warfare (Grace, 2024).

China is also known to be working to deploy an aircraft that acts as a mothership for drone swarms. This 10-ton drone mother ship named Jiu Tian ("Nine Heavens"), is expected to be used to launch a swarm of around 100 loitering munitions for both combat and surveillance (Damein, 2025).

Further, it is also reported that Chinese military has ordered approximately one million drones to be delivered by 2026. These AI enabled drones with anti-tank munitions and an eight hour flight capacity are reportedly to be deployed along the Line of Actual Control with India. Chinese military is conducting combat simulations and drone swarms to train its troop(Manjeet, 2024).

Though China is noted to be one of the leaders in AI advancements, it still has dependencies with other global technologies. While it enjoys a near monopoly in rare earth mineral extraction and processing which can pose vulnerabilities for other global powers, The US and EU partners also leverage their advantages to slow down Chinese AI growth. One such example is ASML, the Dutch company, with encouragement from The US imposing export controls to Chinese companies, thus creating a notable gap for China in advancing its chip technology (Marijan and Ladha, 2024).

On the other hand, China does have its expertise in deployment at scale for lower cost. It is also developing Large Language Models that enables synchronised decision making across the swarm network and encourages faster sense to shoot loops. Meaning, this will advance China's ability to link data analysis, decision making and action within seconds.

Chinese DeepSeek reported to be able to integrate drones, radars and satellites which enables quick and accurate targeting capabilities to help military take decisions. It expects to build

a wide set of algorithm and network driven warfare prowess, that operates at various levels of autonomy by 2030.

Further, it aims for a central command structure for uniformed data sharing, aided by civil and military collaboration that connects commercial technologies to military advancements to accelerate China's efforts in AI. China enjoys an advantage to large drone market that can flood the battlefield with cost effective AI driven platforms that can coordinate for swarming missions.

China's integrated system along with affordable scale makes it a prominent threat in the region and modern warfare. Though China may not have an edge in chips due to sanctions from the west, it is still a leader in AI and algorithm space and an advanced LLM integration through a 'system-of-systems' approach could provide it an edge (Stambamkadi, 2025).

Pakistan

Over the years, Pakistan has delpoyed Turkish drones like Bayraktar TB2s and Songar, China's CH-4 and their own Shahpar-II. It has developed an ability to launch 500 drones in a single operation with reconnaissance, signals intelligence, and tactical loitering munitions capabilities and conduct large scale swarm attacks. It is speeding up its drone procurement by locally assembling Turkish drones in close partnership with China and Turkey. The Turkish YIHA-III kamikaze drone, is reportedly being locally manufactured in Pakistan (Chacko, 2025).

Pakistan's state-owned defence entities, including the National Engineering and Scientific Commission (NESCOM), Global Industrial Defence Solutions (GIDS), and the Pakistan Aeronautical Complex (PAC) located in Kamra, possess the capability and infrastructure to produce a wide range of drone systems.

The Burraq drone variants are being modelled on Chinese CH-3A platform and are being manufactured by NESCOM with China. These Medium Altitude Long Endurance (MALE) drones provide capabilities for surveillance, reconnaissance, and precise strike missions. The Shahpar series viz. Shahpar-I, II, and III—are MALE drones designed for intelligence, surveillance, and reconnaissance (ISR) roles. In addition, the Sarfirsoh kamikaze drones deliver precise attacks using laser-guided munitions. Pakistan Ordnance Factories (POF) has developed the Ababeel MR-

10 multi-rotor drone, equipped with a machine gun, which is utilised for armed reconnaissance and close air support operations (Thakur, 2025).

GIDS recently showcased Blaze-25 loitering munition which is a tube launched and electrically propelled is made specifically for short range missions. This drone is from the family of Blaze-50 and Blaze-75 LMs. It can be used as a standard drone with data linking range of 10 kilometres indicating autonomous targeting features upon deployment to avoid risk of signal spoofing or jamming. GIDS Blaze series focused on cost effectives has AI driven targeting, real-time intelligence gathering, advanced navigation and secure communications (Defence Security Asia, 2025).

A shared characteristic among the various GIDS Blaze sub-variants is their capability to perform a degree of autonomous operation. The developers behind the Blaze series have recognised the increasing prevalence of electronic warfare (EW), which has the potential to interfere with communication data-links and disrupt satellite navigation signals (Quwa, 2024).

Recently, Pakistan imported rotary wing Kargu Kamikaze drone from Turkey's STM. This updated model can vertically takeoff and land, be deployed quickly, can avoid detection with low radar cross sectional area and holds an armour piercing warhead. Kargu is equipped with AI, image-processing function for real-time target recognition and engagement, autonomous navigation for precision strikes (Thakkar, 2025).

Apart from this, Turkey and Pakistan is working on a $900 million drone deal to enhance their UAV precision strike and surveillance capabilities post their failures against India and its Operation Sindoor. This updated agreement will also add in Bayraktar TB2 and AKINCI UAVs and over 700 Turkish loitering munitions (Sharma, 2025).

Despite few projects and initiatives, Pakistan's AI advancement and militarisation has not been significant. It has lagged in developing an AI policy framework and a draft of National AI policy was only released in 2024. Pakistan's economy and a weaker innovation have been bottlenecks for these developments (TPMM, 2024).

It also faces challenges due to its heavy reliance on imports rather than home-grown development even with few own productions. Pakistan Air force launched a Centre for AI and Computing and Training on cognitive electronic warfare in 2020 and their Army launched a Centre for Emerging Technologies focused on AI in cyber-security (Hussain and Khan, 2025).

However, Pakistan is finding advantage with its partners like Turkey and China to build a fleet of Kamikaze drones and is established partnerships with China to enhance their UAVs and AI driven platforms and technologies. Pakistan has also formed a joint venture with China's Chengdu Aircraft company to develop UAVs (Khan, 2025).

One may assume that while India is working towards building its AI capabilities and AI driven LMs with regulations, ethical usage and precision strikes to avoid any civilian damage, Pakistan is majorly focused on procuring large drone swarms through China, Turkey and any other nation that can trade with it irrespective of whether it is following a stringent AI policy, framework or avoiding civilian areas or not.

Hence, it may also be assumed that, while China with its significant AI and language model prowess, mass production capacities is the leading threat to India, Pakistan in itself or as a partner of China would act as a nation without responsibility.

India

India has gained an edge over Pakistan through its homegrown loitering munitions such as ALS-50 by Tata Advanced Systems, Nagastra deep strike Kamikaze drones by solar industries along with use of procured Harop and SkyStriker. This is further powered by India's own defence systems like AI driven Akashteer and Indrajaal. Earlier, India has added 2500 drones into its armed UAV fleet which included IAI Searcher, Heron and LMs from Harpy and Harop, and also U.S. 31 MQ-9B Predator drones (Chauhan, 2025).

However, understanding the significance of homegrown technologies, cybersecurity and geopolitical landscape of procuring defence technology, India has significantly focused on Atmanirbhar (self-reliant) Bharat and indigenisation of their drone fleet. India has made strides in drone and loitering munitions field.

India's homegrown drone arsenal now includes many indigenous drones but not limited to Nagastra from Solar industries and Z-motion autonomous systems Pvt. Ltd; ALS-50 from Tata Advanced Systems Ltd; Switch UAV from ideaForge; Trinetra from AeroArc; Swarm Drone System NewSpace Research & Technologies; FPV Kamikaze Drones jointly developed by Indian Army and Terminal Ballistics Research lab (Swarajya, 2025). The Indian Army has also introduced the 'Kharga' Kamikaze drone that can carry 700 grams of explosives and go undetected with a range of 1.5 kms (Indian Military Review, 2025).

India has prioritised drone technology and is incorporating AI, Autonomous weapon systems, quantum technologies, robotics and algorithmic warfare. India has been working on both viz. drone offense and drone defence capabilities. Further, recognising the need of indigenisation of drone technology, its parts and cybersecurity, India has banned the use of Chinese components in drone manufacturing (Suptnik News, 2023).

The MoD is working to create dedicated audit teams to examine existing military equipments for use of Chinese components. During a recent internal evaluation by the Army, it was discovered that around 400 drones provided by local suppliers incorporated parts sourced from China.

In response, the Army has cancelled its agreements with these manufacturers. Private firms participating in defence procurement processes have been explicitly instructed to ensure their products do not include any hardware or software of Chinese origin. Companies failing to comply with this requirement, risks having their contracts revoked and being barred from future defence contracts (Bharatshakti, 2025).

One good example of 100% indigenisation of kamikaze drones is India's use of Kamikaze drones from a company called IG Drones. These first person drones integrate advanced ISR, terrain intelligence and autonomous response. IG Drones has a 'Zero China Policy' with 85% of hardware made in-house and 100% indigenous core software (Padhi, 2025).

Under the Ministry of Defence (MoD) ADITI 2.O initiative's aim to upgrade existing artillery systems; the Indian Army is procuring ambitious multi-barrel loitering munitions

(MBLM) systems from AeroShul Technologies Pvt Ltd. This will modernise the artillery capabilities for the armed forces, by integrating advanced UAVs that can loitered, survey and perform precision strikes, provide post-strike analysis. These UAVs are set to be coupled with existing artillery rocket systems such as Pinaka multi-launch rocker (MLRS) {Defence Star, 2025}.

One more significant addition is the Bharat Kamikaze drone by National Aerospace Laboratories, which has a 30HP Wankel Engine, a 1000 km range and a speed of 180 KMPH. This can carry a 25kg explosive payload and is developed to operate in GPS denied environment. This helps the drone conduct missions even when GPS signals are jammed (Manufacturing Today, 2024).

The integration of cost-effective Loitering Munitions into India military represents a strategic evolution in modern warfare and aims towards providing an edge to India. However, loitering munitions with autonomy have their own set of challenges to be addressed. As loitering munitions become increasingly advanced and integral to military operations, their level of autonomy is expected to rise.

This evolution, however, introduces serious risks, as the battlefield presents complex challenges—such as debris, smoke, electronic interference, and ongoing combat—which can limit the reliability of the information available to automated systems and lead to errors. Misidentification or misjudgement by autonomous munitions can result in unintended escalation, friendly fire, or harm to civilians.

A major concern with granting more autonomy to these systems is their potential inability to fully grasp the 'commander's intent'—a comprehensive understanding of an operation's objectives and underlying purpose that human operators intuitively share. Even when humans are in charge, clearly communicating and understanding this intent is essential to minimise mistakes.

As autonomy and complexity in military platforms increase, ensuring these systems accurately interpret and act on the commander’s intent will become increasingly challenging. While older, less autonomous loitering munitions face fewer issues in this regard, the widespread deployment of highly autonomous weapons like LAWS will make this challenge far more

pressing. (Madhavan, 2025). Hence, India has been sharpening its autonomous, semi-autonomous, indigenous and AI capabilities in defence technology.

The Solar Defence and Aerospace Ltd. facility has established a state of the art loitering munition test range and a runway for Medium Altitude Long Endurance (MALE) and High Altitude Long Endurance (HALE) drones. The test range will is set to test advanced UAS especially kamikaze drones. The inauguration showcased Nagastra-3 drone by Solar industries which has a 100 km strike range and 5 hours of endurance (DefenceXP, 2025).

India began emphasizing artificial intelligence on a national scale with the introduction of its AI strategy in 2018. The creation of the Defence AI Council and the Defence AI Project Agency in 2019 established a strong institutional foundation for AI-driven defence initiatives. A significant milestone was achieved in 2021, when the Indian Army showcased its autonomous swarm technology using 75 aerial drones during a large-scale military exercise—thus demonstrating its commitment to integrating AI within combat operations.

Looking forward, military insiders indicate that the use of AI will likely expand into areas such as strategic planning, simulation-based wargaming, and comprehensive operational analytics. Future possibilities under consideration include the use of AI for coordinated missions between manned and unmanned systems (MUM-T), advanced perimeter breach detection, and intelligent aircraft identification tools (Sunday Guardian, 2025).

India already has 75 AI powered defence products which are homegrown and range from autonomous drones to smarter surveillance and cyber defence platforms. The tri-services now have their own AI working groups with dedicated annual budgets and roadmaps (India Today, 2025).

The Indian Army already has a roadmap 2026-27 for drone swarms, real-time data analysis, simulated combat training and the use of AI, machine learning (ML), and big data analytics to enhance decision making. The armed forces aim to use AI to enhance data processing from satellite, drones and ground based sensors and aircrafts to integrate real-time data and accurate decision making.

An AI lab to build such tools and applications for three services is said to be built. There is also a strong focus on indigenisation of these technologies custom built with understanding of Indian terrains and needs as seen in the above examples (Sinha, 2025).

Challenges in Usage of AI in Loitering Munitions

Technical Challenges

- **Target Identification and Discrimination**: One of the most critical technical hurdles is enabling AI to reliably distinguish between legitimate military targets and civilians or non-combatants, especially in cluttered or dynamic battlefield environments. Errors can lead to unintended collateral damage or escalation of conflict. AI models may also suffer from biases due to inadequate or skewed training data, thus reducing accuracy and ethical compliance (Human Rights Watch, 2025) (Bonsegna, 2025).
- **Communication and Control Complexity:** Ensuring meaningful human control over autonomous systems is difficult. While some missions require human-in-the-loop authority for engagement decisions, AI-powered drones may operate with minimal supervision due to fast engagement cycles, thus raising risks of loss of control or unintended escalation (Bonsegna, 2025).
- **Robustness Under Adverse Conditions**: Battlefield environments expose loitering munitions to electronic warfare (EW) efforts such as jamming and spoofing, adverse weather, and sensor degradation. AI systems must maintain reliable operation despite these hostile and unpredictable factors, which is a challenging requirement given the current technological limitations (Bonsegna, 2025) (Shankar IAS Parliament, 2025).
- **Opacity and Lack of Interpretability**: Modern AI models, particularly those based on deep learning, are often "black boxes" that provide little transparency into their decision-making processes. This opacity impedes human operators' trust and hampers accountability, as it becomes difficult to audit or understand why a drone acted in a particular way (Riley Simmons-Edler et al, 2025).
- **Adversarial Vulnerabilities:** AI systems in these drones can be susceptible to adversarial attacks wherein enemy forces deliberately manipulate sensor inputs or signals to confuse

or mislead targeting algorithms. This susceptibility makes secure and resilient AI a major challenge (Bonsegna, 2025).

Ethical and Legal Challenges

- **Human Accountability and Compliance:** Autonomous lethal systems challenge traditional frameworks of command responsibility and legal accountability. Questions arise about who is responsible when autonomous systems make targeting errors or violations of international humanitarian law occur. Current technology also struggles to ensure that AI complies fully with the principles of distinction and proportionality (Human Rights Watch, 2025) (Bonsegna, 2025).
- **Absence of a Unified Regulation:** There is no comprehensive global regulation specifically addressing AI-enabled autonomous weapons. Instead, a patchwork of partial policies and guidelines exists internationally, creating inconsistencies in deployment, oversight, and export controls (Dohnal, 2025).

Operational and Strategic Challenges

- **Integration with Existing Systems**: Embedding AI-powered loitering munitions into complex battlefield networks requires seamless interoperability with command and control systems, real-time data linkage, and robust cyber-defence—all of which are demanding to implement effectively (Riley Simmons-Edler et al, 2025).
- **Speed of Development vs. Safe Deployment:** Rapid advances in AI and military drone technology risks outpacing the development of doctrine, testing protocols, and safeguards. This can lead to deployment of under-tested systems with the potential for malfunction in combat (Riley Simmons-Edler et al, 2025); (Human Rights Watch, 2025).
- **Cost and Resource Constraints:** Developing, validating, and maintaining AI capabilities require significant investment in data infrastructure, software development, testing environments, and training. These high costs and resource demands can be a barrier, especially for nations trying to indigenise technology.

Strategies for Effective AI Deployment in Defence

Below ideas would help a nation in deploying AI in defence whilst considering technical, legal and operational issues (Ousmer, 2025) (Keating et al, 2025).

- **Integrate AI Incrementally into Legacy Systems**: Many defence organisations still use outdated systems not compatible with AI. Gradual integration alongside current hardware and software—using middleware or APIs—and upgrading processing power while training personnel enables modernisation without disrupting operations. This approach reduces costs and risks, slowly transforming legacy systems into AI-driven defence networks.
- **Balance Speed and Accuracy with Human Oversight:** Defence AI must balance fast decision-making with accuracy. A two-step process—quick threat detection followed by detailed analysis—reduces false alarms and builds operator trust. Human judgement remains critical, with commanders using AI insights as support while giving final approvals. Continuous feedback enhances performance, ensures safety and helps in responsible use of AI.
- **Prioritise Data Security and Sovereignty**: Defence AI handles sensitive data requiring strict security and national control. This includes encrypted, isolated networks, local data processing (edge computing), and strict access management. Embedding security early builds trust, avoids costly retrofits, and ensures compliance with legal standards, hence allowing safe use of powerful AI tools.
- **Build a Multi-Layered AI Deployment Framework**: AI in defence works best as a layered system: edge devices perform real-time threat detection; command centres analyse and coordinate missions; cloud platforms provide strategic support. This design boosts scalability, reliability, and resilience, as other layers can compensate if one fails, creating a flexible ecosystem.
- **Foster Collaboration and Partnerships Across Military, Industry**: Effective AI adoption needs strong collaboration among military, industry, tech firms, and academia. Sharing expertise speeds research and prototyping; universities develop AI talent; partnerships help manage risks and accelerate growth. International cooperation promotes shared ethics, interoperability, and consistent AI use, thus addressing complex defence challenges.

- **Update Military Doctrine and Training:** Military personnel require targeted training on ethical AI use and human oversight. Simulation-based programs prepare officers for managing autonomous systems responsibly. Updated doctrines must define AI policies, ethical standards, human control protocols, and operational limits, along with education on AI capabilities and international law.
- **Need for Ethical Guidelines in Commercial AI Development:** The commercial sector plays a vital role in ethical AI development for defence. Companies must prioritise transparency, accountability, and legal regulatory standards. Establishing ethics boards, diverse teams, algorithm audits, whistleblower protections, and corporate accountability helps ensure responsible AI innovation and lawful autonomous weapons development.

A Look at Challenges in Building Indigenous Drone Strength

While India has been forging public, private and academic partnerships, and encouraging indigenisation of defence technologies, it does face certain challenges. The US and its favouring nations have the superior edge of procuring AI chips and AI/computer infrastructure. China has its strengths in AI systems and algorithms. India has seen growing defence tech startups and big players but still faces challenges with large scale AI computing infrastructure, AI skillset and gaps in manufacturing and procurement as mentioned below (InsideFPV, 2025).

- **Dependence on Imported Components:** India needs to shift its reliance from imported essential drone components to avoid national security risk. Domestic production of critical hardware like LiDAR and microchips is limited. While companies like Zuppa have advanced indigenous autopilot tech, scaling remains difficult due to high R&D costs and a weak local supply chain. The 2022 import restrictions aim to boost localisation by 2026, but success depends on stronger government incentives, academia-industry ties, and sustained investments beyond assembly.
- **Inconsistent Regulatory Framework**: Though Drone Rules 2021 aimed to ease approvals, slow certifications and airspace clearances continue. The Digital Sky platform is underused and complex. A key unresolved issue is the lack of clear Beyond Visual Line of Sight (BVLOS) regulations, causing uncertainty for drone delivery and surveillance

firms. Faster approvals, wider Digital Sky adoption, and clear BVLOS norms are crucial for industry growth.

- **Cybersecurity Vulnerabilities**: Use of off-the-shelf parts and foreign software makes Indian drones vulnerable to hacking, GPS spoofing, and data leaks, especially in sensitive areas. Progress in tamper-resistant systems is slow due to limited cybersecurity R&D. Since 2025, India has begun focusing on AI-secure communications and collaborating with DRDO to build a trusted drone technology stack.

One example could be the quick adoption of post-quantum cryptography drones which could take a 5-6 year migration time; need for adoption of indigenous atomic clocks into India's NavIC system to power drones and 100% overcoming of Global Navigation Satellite System (GNSS); and also quicken the use of 7-15 nm size chips and processors in FPV drones (Singh, 2025).

- **Limited Skilled Workforce**: A shortage of trained engineers, pilots, and AI experts limits innovation. Limited specialised education and high training costs contribute to the skill gap, expected to persist until 2028. Expanding partnerships with technical institutes and subsidising training programs are vital to build the workforce.
- **High R&D Costs and Funding Gaps**: Advanced drone development requires significant capital, which remains limited. Venture capital favours consumer tech over deep tech like drones. Although, PLI supports some efforts, more funding—raising TDF grants and creating drone-specific VC funds—is needed to boost research and growth.

Addressing the Challenges and Way Forward

To emerge as a major drone power, India should look at policy, talent and infrastructure (Padhi, 2025).

- **Core Technology Innovation**: India needs to move beyond merely assembling drones and focus on foundational technology advancements. Key areas include developing improved battery systems for longer endurance, sophisticated autonomous swarming algorithms for coordinated multi-drone operations, enhanced resilience against electronic warfare (EW) threats, and AI-driven predictive mission systems that can anticipate battlefield dynamics.

Investing in these cutting-edge innovations is essential not only to achieve superior drone performance but also to establish a credible strategic deterrent in modern warfare.

- **Co-Development Through R&D Investment:** To build a resilient and innovative drone ecosystem, the government and strategic defence buyers must actively support early-stage research and development partnerships with domestic drone manufacturers. Collaborative co-development enables creation of customised solutions tailored specifically for India's security environment and operational needs. This approach encourages a steady stream of innovation, reduces reliance on foreign imports, and ensures intellectual property remains under national control, hence strengthening India's technological sovereignty.
- **Supply Chain Localisation:** Achieving self-reliance in key drone components is fundamental. Efforts should prioritise scaling up indigenous production of critical parts such as advanced battery cells, high-precision sensors, and lightweight composite materials. Targeted incentives through Production Linked Incentive (PLI) schemes can stimulate domestic manufacturing growth. Additionally, the establishment of specialised drone manufacturing hubs near defence industrial clusters can create focused ecosystems that accelerate development, testing, and production, thus fostering a vibrant local supply chain and reducing import dependencies.
- **Regulatory Simplification**: A simplified and unified regulatory framework is crucial to encourage innovation and expedite market entry for indigenous drone startups and Micro, Small, and Medium Enterprises (MSMEs). Implementing a single-window digital platform for all necessary approvals can minimise bureaucratic delays. Complementing this with fast-track testing infrastructure and streamlined procurement procedures will help lower the barriers to entry and accelerate the adoption of homegrown technologies within defence and civilian sectors.
- **Speed and Agility in Procurement:** To bridge the gap between innovation and operational deployment, defence and homeland security agencies must adopt more flexible and agile procurement practices. Faster acquisition cycles, combined with the willingness to deploy tested indigenous drone platforms promptly, will ensure that innovations rapidly transition from laboratories to the battlefield. This agility is critical for keeping pace with evolving

threats and closing capability gaps efficiently, hence reinforcing India's defence preparedness and technological edge.

Conclusion

It is clear that drone offence and defence is the new normal for the world and all world powers are actively pursuing to build these capabilities. The US has its AI chips, infrastructure and computing capabilities, China has its AI platforms and algorithmic edge, Pakistan has its core aim to spend all the expense possible from its bleak economy to develop or procure defence technologies against India leveraging its connections with China and Turkey. India is at a pivotal stage to become a power to recon with through its Atmanirbhar (Self-reliant) vision and clear message against terrorism or its backers during Operation Sindoor.

Hence, the advancements in AI or its applications in defence technologies is a crucial step towards securing the strategic future of India; for that, India needs to take a self-reliant journey, navigating geo-political pressures and internal politics, incur some costs for a stronger future.

Though the path forward is challenging, these hurdles can be overcome. Achieving this transformation demands a shared commitment—an agile collaboration among government, industry, and academia—to safeguard India by prioritising rapid progress, expansive growth, and self-sufficiency.

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