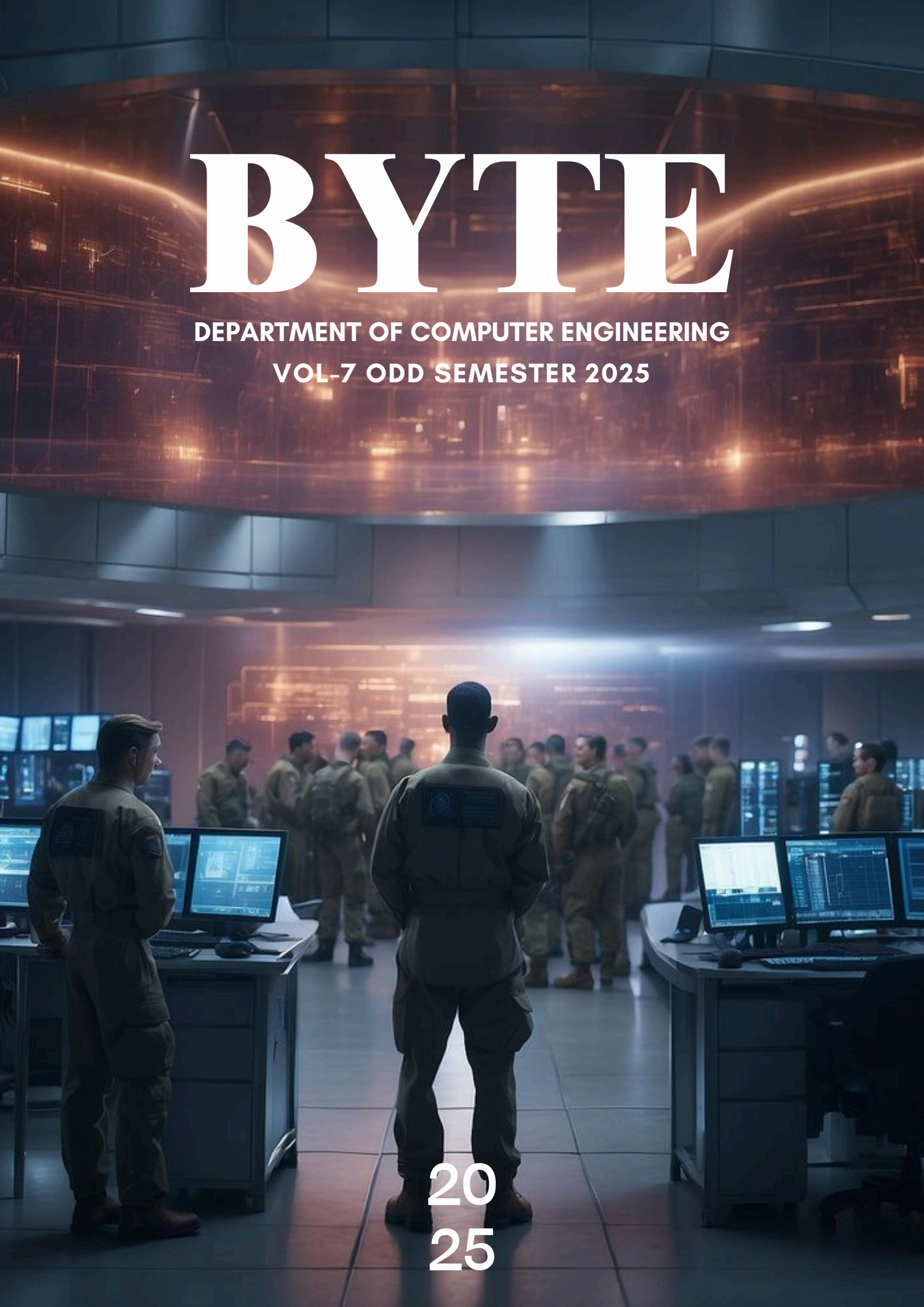

# BYTE

DEPARTMENT OF COMPUTER ENGINEERING

VOL-7 ODD SEMESTER 2025

2025

# VCET's
# Vision and Mission

## Vision

To be a premier institution of technical education, aiming at becoming valuable resource for the industry and society.

## Mission

- To provide a technologically inspiring environment for learning.
- To promote creativity, innovation and professional activities.
- To inculcate ethical and moral values.
- To cater to personal, professional and societal needs through quality education.

# Our Department's

## Vision and Mission

### Vision

To evolve as a center of excellence in the field of Computer Engineering to cater to the industrial and societal needs.

### Mission

- To provide quality technical education with the aid of modern resources.
- To inculcate creative thinking through innovative ideas and project development.
- To encourage Life-long learning, leadership skills, entrepreneurship skills with ethical and moral values.

# A few words about us..

As engineers, most of us share one particular hobby-innovation. We get excited about new tech, we watch keynotes, unboxing and review videos of cool new gadgets and are keen to know more and dream of owning the same.

We are just a bunch of tech enthusiasts from the Department of Computer Engineering at VCET and BYTE is a means for all of us to share this info.

BYTE started in 2003 with ideas as inspirations as a newsletter. 22 years later, in the world of new generation with new taste, we brought you BYTE with an update: The BYTE E-Magazine! For you the 6th volume of the BYTE E-Magazine is here.

।।सर्वं ज्ञानं मयि विद्यते।।
"Sarv gyaanam mayi vidyate"
"All that I have to learn is within me"

# From the desk of BYTE in-charge,

।।सर्वं ज्ञानं मयि विद्यते।।-

Eternal Knowledge lies within us. To gain that eternal knowledge we need the knowledge of the existing advancements in the domain. BYTE is a small effort in the direction to help future engineers acquire knowledge relevant to technology. As a proud VCETian, our cherished motto is "overall empowerment of students" for their all-round development. Today, education means much more than merely acquiring knowledge. Our focus has been on the acquisition of knowledge and skills, building character and improving the employability of our young talent. I am sure that VCET's culture, and an inherent strong foundation that the institution has provided to our students, has assisted them to march ahead and achieve their educational objectives ensuring a stronger and brighter future. To continue with this culture and support students, I presented my brain child departmental newsletter, "BYTE", in 2003. It continued to cater the technical and innovative needs of many curious students till today. With such a steady stream of initiative taken, it makes me proud to be the faculty in-charge and patreon of this venture. Today my brainchild has taken a new form as an E-Magazine, which is first of its kind. The new E-Avatar of BYTE is full of great technical stuff and the stuff in the art of life to quench the thirst of the curious. Here with great honour present to you, new "BYTE" - the E-Magazine of the Department of Computer Engineering, VCET. Happy reading!

**Mr. Vikrant A. Agaskar**

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# 1. THE ROLE OF AI IN TRANSFORMING GLOBAL DEFENSE AND EMPOWERING INDIAN INNOVATION

Artificial Intelligence (AI) is at the forefront of modernizing global defense. It is being used for predictive analytics to inform strategic planning, real-time threat detection, and autonomous weapons systems. In India, AI is a key focus for the defense sector, with a push to integrate it into everything from logistics and intelligence gathering to combat systems, aiming to reduce human error and improve operational efficiency. The Defence Institute of Advanced Technology (DIAT) is a key player, focusing on AI-based unmanned ground vehicles and deepfake detection software.DRDO and BEL have collaborated on AI-assisted image recognition for border surveillance.

Meanwhile, Grene Robotics has developed Indrajaal, an autonomous drone-defence dome system (C-UAS) that uses AI to monitor and neutralize drone threats over wide areas; its deployments now include naval and critical infrastructure sites in Gujarat.

On the PSU side, Bharat Electronics Limited (BEL) has expanded its AI-incubation efforts: its Army AI Incubation Centre is now producing AIbased tools already in use by the forces namely in predictive maintenance systems for sensors and weapons, and in voice-analysis and document-management software for situational awareness.

# 2. THE DIGITAL ADVANCEMENTS REDEFINING AERIAL WARFARE

Aerial warfare is being revolutionized by digital advancements. Active Electronically Scanned Array radars and advanced sensors are being integrated into fighter jets like the Rafale and Tejas to enhance detection and engagement capabilities against multiple targets simultaneously. The procurement of MQ-9B drones from the US is aimed at enhancing surveillance and providing precision-strike capabilities, particularly in the Indian Ocean Region. This technology allows for real-time intelligence and a significant increase in situational awareness. India's upgrade roadmap for the Su-30MKI also includes indigenous Uttam AESA radar integration, reducing reliance on imported technology.

India’s DRDO has unveiled the Virupaksha AESA radar for the Su-30MKI upgrade program (“Super-30”). This GaN-based Active Electronically Scanned Array radar, with around 2,400 Transmit/Receive (T/R) modules, will replace the older Russian N011M “Bars” radar. It reportedly gives detection ranges of 300-400 km for fighter-sized targets and improved thermal management, power efficiency, and lighter weight.On the MQ-9B front: India has signed a contract for 31 armed MQ-9B drones (SeaGuardian & SkyGuardian variants) from the US. Under this deal, deliveries are expected between 2029 and 2030.

Also, the IAF has contracted indigenous ‘Ashwini’ AESA radars from DRDO/BEL. These radars feature 4D surveillance (scanning in azimuth & elevation), integrated IFF systems, and ECCM capabilities.

# 3. ARTIFICIAL INTELLIGENCE IN INDIA'S DEFENSE ECOSYSTEM

India is strategically pushing to use AI to enhance its defense capability. AI-driven systems are being developed for faster and more accurate decision-making, reducing human error, and improving operational efficiency. Already, Indian Army formations in Eastern Ladakh are experimenting with AI-driven logistics models that predict fuel, food, and ammunition requirements based on troop movements and terrain.

AI is being tested for predictive maintenance of warships, while in the Air Force, AI algorithms are being used to analyze flight data to improve safety and combat performance. NRT also showcased its Sheshnaag swarming unmanned air systems (SUAS) at Aero India 2025.

The swarm maintained encrypted communications and payload telemetry back to a ground control station over a large distance with minimal latency.

Bangalore-based NewSpace Research & Technologies (NRT) delivered the first batch of its Tethered Drone Solutions (Nimbus Scope model) to the Indian Army under the Fast Track Procurement (FTP) mechanism.

The Kaala Bhairav MALE combat drone (by FWDA) was unveiled in August 2025. It promises ~30-hour endurance, is domestically developed, and is designed for swarm strike capability.

# 4. THE RISE OF UNMANNED AND AUTONOMOUS SYSTEMS

Unmanned Aerial Vehicles (UAVs) and Unmanned Ground Vehicles (UGVs) are becoming central to modern military operations. These systems can operate in high-risk areas, reducing the danger to personnel. The development of a stronger manufacturing ecosystem for military-grade drones is a top priority for India's armed forces. The Indian Army has placed orders worth ₹295 crore for loitering munitions and drones. One contract (≈ ₹158 crore) is for about 450 Nagastra-1R loitering munitions (kamikaze drones) capable of night operations from Solar Defence & Aerospace Ltd.

The other (≈ ₹137 crore) is with ideaForge for hybrid mini-UAVs (Switch variants with VTOL) for ISR (intelligence, surveillance, reconnaissance) missions.

Kaala Bhairav combat drone by Flying Wedge Defence & Aerospace unveiled in August 2025: a MALE drone with ~30-hour endurance, designed for swarm strike capability, and claimed cost advantage relative to Predator-class drones.

HAL's CATS Warrior ("loyal wingman" drone) prototype displayed at Aero India 2025; part of the Combat Air Teaming System (CATS) programme.

# 5. CYBER WARFARE AND ELECTRONIC DEFENSE

Cybersecurity and electronic warfare (EW) are critical components of modern defense. Cyberwarfare targets digital infrastructure, and EW is used to disrupt enemy communications. India is focused on developing a unified cybersecurity policy to protect its defense ecosystem. Systems like the Spectra electronic warfare suite on the Rafale fighter jets enhance India's ability to disrupt enemy communications and ensure its own systems are protected. DRDO has also indigenously developed EW suites for Sukhoi and MiG aircraft, which can jam enemy radars and missile guidance systems. The armed forces are now seeking new “digital swords”—AI-powered cyber tools for countering misinformation, deepfake detection, and training in simulated cyber-ranges, reflecting the shift towards information warfare preparedness.

In April 2025, the Ministry of Defence signed a ₹2,385 crore contract with Bharat Electronics Limited (BEL) to equip Mi-17 V5 helicopters with advanced electronic warfare suites. These include Radar Warning Receivers, Missile Approach Warning Systems, and Counter Measure Dispensing Systems, significantly boosting survivability in contested zones.

Odisha inaugurated its first Deep Neural Network (DNN) Lab in June 2025, dedicated to AI-enabled electronic warfare, cyber defence, radar signal processing, and space surveillance, marking a major push in indigenous R&D.

# 6. SPACE-BASED TECHNOLOGIES FOR INDIAN DEFENSE

Space-based technologies are crucial for modern defense, providing capabilities such as satellite communications, global positioning, and reconnaissance. India is investing heavily in this domain. While China has a significantly larger number of military satellites, India's indigenous expertise in satellite launch and surveillance is exemplary. The use of satellites for real-time intelligence transmission is a key area of focus to enhance India's strategic advantage.

India has launched a fast-track program under Space-Based Surveillance Phase-3 (SBS-3) to deploy 52 defence surveillance satellites by 2029. The project cost is about ₹26,968 crore, aimed at enhancing real-time, high resolution monitoring of borders, adversary infrastructure, and Indian Ocean Region.

Under this program, ISRO will build 21 satellites, while three private firms are to develop and deploy the remaining 31 satellites, reflecting increasing inclusion of private sector in national defence space missions.

The first of the SBS-3 satellites is planned to be launched by April 2026, and full deployment (i.e. all 52 satellites) is targeted by end of 2029.

A dedicated military communication satellite for the Indian Navy, GSAT-7R, is being prepared to replace the older GSAT-7 (“Rukmini”). It is expected to weigh about 2,650 kg, operate in geostationary orbit, cost roughly ₹1,589 crore, and enhance secure real-time networking among naval platforms.

# 7. HYPERSONIC WEAPONS: A NEW FRONTIER IN MODERN WARFARE

Hypersonic missiles, which travel at Mach 5 or faster, are a significant leap forward in military technology. Their speed and maneuverability make them incredibly difficult to intercept with traditional defense systems. India is actively working on developing its own hypersonic weapons. Globally, nations are investing in this technology to gain a strategic edge, and the development of effective countermeasures is a key area of research.

DRDO (Defence Research and Development Organisation) has recently tested a ground-based active cooled combustor for a scramjet engine, holding combustion stable for 120 seconds. This is a key step toward hypersonic missile development.

In April 2025, DRDO’s Defence Research & Development Laboratory (DRDL) conducted a long-duration ground test of a subscale scramjet active-cooled combustor at the newly built Scramjet Connect Test Facility in Hyderabad. This test ran for over 1,000 seconds (almost 17 minutes), marking a major advancement beyond the earlier 120-second tests.

The ET-LDHCM (Extended Trajectory Long-Duration Hypersonic Cruise Missile), developed under DRDO’s Project Vishnu, has been reported in tests around mid-2025 to achieve speeds of Mach 8 and a strike range of ~1,500 kilometers. Its design incorporates mid-flight manoeuvrability, low-altitude flight profiles to help avoid radar detection, and resilient materials to endure extreme thermal stress.

# 8. QUANTUM COMPUTING'S ROLE IN SECURING DEFENSE COMMUNICATION

Quantum computing holds immense potential for defense. It can provide impenetrable communication networks and encryption techniques, safeguarding classified information from cyber threats. For India, this technology is considered critical for securing its defense operations and maintaining a technological edge in the face of evolving digital threats.

India is accelerating work to achieve quantum-secure defence communications: Contracts have been awarded to companies like QuNu Labs for quantum secure key distribution systems.

India’s DRDO has opened the Quantum Technology Research Centre (QTRC) in Delhi (Metcalfe House) to develop defence-oriented quantum capabilities. It includes experimental setups for quantum key distribution, photonic systems, atomic clocks, magnetometers, and secure lasers.

he Indian Army has developed indigenous Post-Quantum Cryptography (PQC) applications via the Corps of Signals and the Military College of Telecommunication Engineering (MCTE), Mhow. These are being gradually integrated into its communication networks to protect against future quantum threats

# 9. MODERNIZING INDIA'S MILITARY: THE TECHNOLOGY PERSPECTIVE CAPABILITY ROADMAP (TPCR) 2025

The Technology Perspective Capability Roadmap (TPCR) 2025 outlines India's 15-year defense modernization plan. It emphasizes indigenization, advanced technology, and public-private partnerships. The roadmap was released during the tri-service seminar “Ran Samwad 2025,” along with a joint doctrine for multi-domain operations (MDO).

Procurement plans include over 1,800 next-generation main battle tanks and 400 light tanks tailored for mountain / high-altitude terrain.

The roadmap lists over 200 weapon systems and tech items for development / procurement over the 15-year period.

Strategic Doctrines: In conjunction with the TPCR, the Joint Doctrine for Multi-Domain Operations (MDO) was released. This doctrine provides a framework for integrated operations across land, sea, air, space, cyber, and cognitive domains, aiming to enhance jointness and future operational readiness among the Indian Armed Forces.

Weapon Systems and Technologies: Over 200 weapon systems and technological items are slated for development and procurement over the 15-year period. These encompass advancements in hypersonic missiles, nuclear propulsion, artificial intelligence, unmanned aerial systems, and directed-energy weapons

# 10. COMPARATIVE ANALYSIS: INDIA'S INDIGENOUS DEFENSE SYSTEMS VS. INTERNATIONAL COUNTERPARTS

India’s defense sector has undergone a major shift under ‘Make in India’ and Atmanirbhar Bharat, reducing dependence on imports and positioning itself as a rising defense exporter. Indigenous systems like the Akash and upgraded Akash NG missiles offer cost-effective air defense, comparable to the US Patriot PAC-3 and China’s HQ-9, while the upcoming XR-SAM will provide 250 km coverage, complementing India’s imported S-400 systems.

India is also focusing on next-gen threats. Bhargavastra (C-UAS) and DRDO's D4 counter-drone systems can detect, jam, and neutralize swarms, a capability on par with Israel's Drone Dome. The Ballistic Missile Defense (BMD) program, with AD-1 and AD-2 interceptors, puts India among the few nations with a two-layer missile shield.

In air power, the induction of Tejas Mk-1A and development of Tejas Mk-2 and AMCA stealth fighter reflect progress toward self-reliance, while UAV projects like Rustom-II, Ghatak UCAV, and ALFA-S swarm drones prepare India for future unmanned warfare.

Naval power is expanding with INS Vikrant, Arihant-class SSBNs, and the planned SSN fleet, ensuring dominance in the Indian Ocean. India is investing in AI-driven surveillance, autonomous vehicles, military satellites, and early work on hypersonic glide vehicles, signaling a move toward network-centric, future-ready warfare. To stay competitive with the US, Russia, and China, India must accelerate indigenous propulsion, stealth technologies, and AI-enabled command-and-control systems.

# 11. INDIA'S DEFENSE PROCUREMENT AND INDIGENIZATION PUSH

India is actively reducing its reliance on foreign military imports through the 'Make in India' and 'Atmanirbhar Bharat' initiatives. This is evident in recent defense deals, such as the procurement of 114 Rafale jets with a high degree of indigenous content and the local manufacturing of C295 transport planes. Public-private partnerships have been instrumental in scaling production and fostering innovation, with private firms contributing to projects like the Tejas Light Combat Aircraft and the Arjun Main Battle Tank.

114 ‘Make in India’ Rafale Jets Proposal

The Indian Air Force (IAF) has submitted a proposal to acquire 114 Rafale jets under a “Made in India” scheme. The deal is estimated at over ₹2 lakh crore.

Importantly, it envisages more than 60% indigenous content, including local manufacturing and involvement of Indian aerospace firms.

Also, Tata Advanced Systems (TASL) and Dassault have agreed to manufacture the fuselage of these Rafales in Hyderabad — a first time such sections are being produced outside France. The facility is expected to deliver fuselages by FY 2028.

Rafale-Marine Jets for Indian Navy : India also cleared the deal to buy 26 Rafale-Marine jets for the Navy (22 single-seaters + 4 twin-seat) for ~₹63,000-₹64,000 crore.

The agreement includes indigenous component manufacture (offsets) and integration of Indian weapons systems.

# 12. GLOBAL TRENDS IN MILITARY TECHNOLOGY

The global defense landscape is defined by several key trends. These include the widespread adoption of AI and autonomous systems, the development of hypersonic weapons, and the increasing importance of space-based and cyber technologies. Countries are focusing on integrating these technologies to create multi-domain capabilities and enhance their strategic positions. The shift towards low-cost, high-tech solutions is a major takeaway from recent conflicts.

Hypersonic weapons, which travel at speeds exceeding Mach 5, offer unprecedented speed and maneuverability, making them difficult to intercept.

Countries like the United States, Russia, China, and India are racing to develop both hypersonic cruise missiles and glide vehicles.

AI & Autonomous Systems

AI is now embedded in ISR systems, threat detection, predictive logistics, and autonomous targeting.

Autonomous drones and loitering munitions are being deployed at scale (e.g., Ukraine using AI-enabled drone swarms for precision strikes).

U.S., China, and Israel are integrating AI into C4ISR and semi-autonomous combat systems.

Space and Cyber Technologies

Space is increasingly treated as a contested domain: e.g. satellites being hijacked or impacted via cyber means (Ukraine/Viasat, etc.).

China and Russia’s actions in space, and Western responses, are being viewed as urgent threats.

# 13. THE INTERNET OF MILITARY THINGS (IOMT)

The Internet of Military Things (IoMT) is the defense adaptation of the Internet of Things, where interconnected devices, sensors, and communication systems create an intelligent military network. It enables real-time data exchange between soldiers, vehicles, drones, satellites, and command centers, greatly improving situational awareness and decision-making. Wearable sensors, smart helmets, and exoskeletons track soldiers' health and location, while UAVs, ground robots, and swarm drones provide surveillance, reconnaissance, and autonomous mission support. Edge computing and 5G/6G technologies power ultra-low latency communication, while AI and ML analyze large data streams to predict threats, detect anomalies, and support proactive strategies. Blockchain and cybersecurity frameworks secure IoMT operations, while sensor-enabled uniforms, biometric authentication, and geofencing further enhance security and battlefield readiness.

Beyond direct combat, IoMT supports connected armored vehicles, smart munitions, predictive maintenance of aircraft and vehicles, and real-time supply chain monitoring to reduce downtime and ensure mission success. Naval and air defense systems integrate submarines, ships, radars, and aircraft for coordinated threat detection, while AR/VR strengthens soldier training with realistic simulations. Cloud-enabled architectures and hybrid command centers combine AI insights with human oversight for strategic mission planning, and allied forces can collaborate through shared IoMT intelligence. Smart border surveillance, underwater IoMT networks, and disaster-response coordination highlight its versatility. Despite challenges like cybersecurity risks, interoperability, and high costs, IoMT is rapidly transforming modern warfare into a more data-driven, interconnected, and intelligent ecosystem.

# 14. ADDITIVE MANUFACTURING (3D PRINTING) IN DEFENSE

GAME CHANGER

Additive manufacturing, commonly known as 3D printing, is revolutionizing defense production worldwide by enabling the rapid prototyping and on-demand manufacturing of complex components that were previously difficult or impossible to produce using traditional methods. This technology significantly reduces costs, shortens lead times, and minimizes material waste by building parts layer by layer directly from digital designs.

In defense applications, additive manufacturing is being employed to develop critical components for missiles, unmanned aerial vehicles (UAVs), armored vehicles, and protective gear. Its ability to create lightweight, highly durable parts with intricate geometries improves the performance and survivability of military equipment. For example, complex engine parts, sensor housings, and custom-fitted body armor can be produced faster and tailored to specific mission requirements.

In India, the adoption of additive manufacturing is playing a pivotal role in accelerating indigenous defense production and reducing reliance on imports. The technology supports the ‘Make in India’ initiative by streamlining the supply chain, enabling localized production of spare parts and reducing dependency on foreign suppliers, which is crucial during times of conflict or geopolitical tensions. Indian defense research organizations and private sector players are increasingly investing in advanced 3D printing capabilities to enhance the design and manufacturing of critical systems, including drones, missile components, and communication devices.

Overall, the integration of additive manufacturing in defense production not only boosts operational efficiency and self-reliance but also fosters innovation in developing next-generation military technologies suited to evolving threats and strategic requirements.

# 15. THE FUTURE OF DEFENSE: HUMAN-MACHINE TEAMS

The future of warfare is about building effective human-machine teams that combine the unique strengths of both. AI and autonomous systems will support soldiers by rapidly analyzing data, detecting threats, and providing combat assistance, enabling quicker and better-informed decisions. This partnership enhances military capabilities by merging the precision and speed of machines with the strategic thinking and adaptability of humans.

Autonomous systems can scout dangerous areas, handle routine tasks, and support logistics by delivering supplies, reducing risks to soldiers. This collaboration increases flexibility and resilience in fast-changing combat environments across land, air, sea, cyber, and space domains. Human oversight remains crucial to ensure ethical use and compliance with rules of engagement.

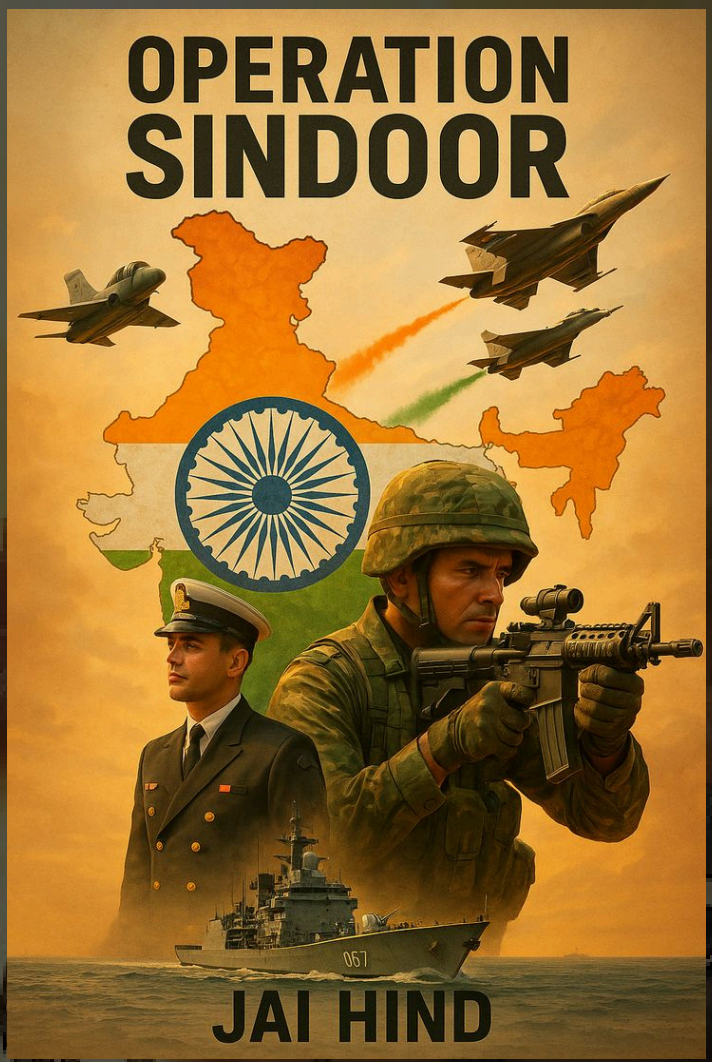
Moreover, AI-driven training and simulation tools prepare soldiers to operate seamlessly alongside autonomous systems, enhancing their skills in decision-making, coordination, and adaptability under realistic combat conditions. These advanced training platforms allow for continuous learning and scenario-based practice without the risks and costs of live exercises, ultimately improving readiness and reducing casualties on the battlefield. As defense forces worldwide continue to invest heavily in AI and autonomous technologies, the development of human-machine teams will be key to shaping the future of warfare. This collaboration will enable armed forces to respond more swiftly and effectively to emerging threats, maintain strategic superiority, and adapt to the increasingly complex and multidimensional nature of modern conflict environments.

# Operation Sindoor: Overview & Technology

Operation Sindoor was India's decisive military campaign launched on May 7, 2025, in response to the April 22 Pahalgam terror attack that killed 26 civilians. It targeted terror camps of LeT, JeM, and Hizbul Mujahideen across the LoC and inside Pakistan.

Objective: Eliminate terror infrastructure without escalating into full-scale war.

Execution: Precision air strikes on at least nine sites; Navy provided surveillance and defence cover;



**Electronic Warfare & Space:**
Electronic Warfare (EW) Systems: Indigenous EW systems, developed by DRDO and produced by BEL, were successfully used to jam Chinese-supplied air defense systems of Pakistan.

**Satellite Technology:** The Indian Space Research Organisation (ISRO) played a crucial role, with at least 10 satellites providing continuous surveillance and situational awareness to the armed forces.

**Command and Control:**
The operation highlighted the importance of a networked and integrated command structure. The Integrated Command and Control Strategy (ICCS) facilitated real-time threat identification and interception across multiple domains.


**VIDYAVARDHINI'S COLLEGE OF ENGINEERING & TECHNOLOGY, VASAI**

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