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The Study of Artificial Intelligence in Modern Defence System

Dr. Goldi Soni[1], Ayush Dewangan[2], Sanyyam Doye[3]
[1]*Assistant Professor, Amity University Chhattisgarh*
[2, 3]*B.Tech(CSE), Amity University Chhattisgarh*

Abstract: ***The integration of Artificial Intelligence (AI) in modern defence has transformed the landscape of military operations, intelligence, and strategic decision-making. This review synthesizes findings from thirty-seven recent research papers that explore AI applications across domains such as surveillance, autonomous systems, cyber defence, logistics, and ethical governance. Studies highlight AI's role in enhancing situational awareness through satellite and sensor fusion, improving decision-support via predictive analytics, and enabling autonomy in unmanned aerial and ground vehicles. Research further emphasizes advances in military logistics optimization, AI-driven wargaming, and natural language models for multilingual intelligence analysis. At the same time, concerns over adversarial attacks, bias, explainability, and the ethical use of AI in lethal autonomous weapon systems remain critical challenges. Policy-focused works underscore the necessity of human-in-the-loop frameworks and international governance mechanisms to ensure responsible deployment. Collectively, the literature demonstrates that while AI offers unprecedented opportunities to strengthen defence capabilities, its adoption must be balanced with ethical safeguards, interoperability standards, and robust oversight to maintain security, accountability, and global stability.***
Keywords: Artificial Intelligence, Modern Defence, Autonomous Systems, Cyber Defence, Military Logistics, Ethical Governance, Decision-Support Systems.

I. INTRODUCTION

A. Needs

The rapid evolution of modern warfare, characterized by asymmetric threats, cyber intrusions, and the growing complexity of battlefields, has created an urgent need for advanced technological solutions in defence. Traditional methods of surveillance, decision-making, and resource deployment often fall short in handling the speed and scale of present-day conflicts. AI addresses this gap by providing real-time data analysis, predictive threat assessment, and autonomous capabilities that enhance operational efficiency. Nations are increasingly investing in AI-driven defence systems to counter emerging challenges such as drone swarms, electronic warfare, and sophisticated cyberattacks. This need stems from the imperative to maintain strategic superiority and ensure national security in a highly dynamic global security environment.

B. Definition

Artificial Intelligence (AI) in the defence sector can be defined as the integration of machine learning algorithms, intelligent systems, and computational models into military processes to augment human decision-making and operational capacity. It encompasses diverse applications ranging from automated surveillance, natural language processing for intelligence analysis, and predictive maintenance of military assets to autonomous weapons and robotic platforms. Unlike conventional computational tools, AI systems are capable of learning from data, adapting to new conditions, and improving their performance over time. In the context of defence, this means creating systems that can operate in complex, uncertain, and adversarial environments with a high degree of autonomy while remaining under human oversight.

C. Importance

The importance of AI in modern defence lies in its ability to revolutionize the speed, accuracy, and scope of military operations. AI-powered systems enhance situational awareness by fusing data from multiple sources, enabling commanders to make faster and more informed decisions. In addition, AI optimizes logistics, strengthens cybersecurity, and supports mission planning through simulations and predictive analytics. The growing use of autonomous drones, surveillance platforms, and AI-driven decision-support systems demonstrates how indispensable the technology has become to modern militaries.

Beyond operational efficiency, the strategic importance of AI lies in its role as a force multiplier, allowing nations to maintain a technological edge while addressing ethical and governance concerns to ensure responsible use.

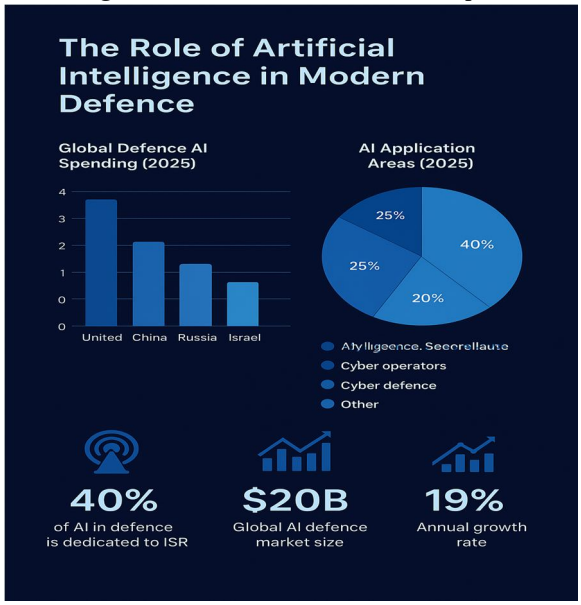

Figure 1: The Role of Artificial Intelligence in Modern Defence

This figure highlights the growing strategic importance of Artificial Intelligence in the modern defence sector by presenting key statistics for 2025. It shows how leading nations like the United States, China, Russia, and Israel are investing heavily in AI for military applications, reflecting its role in maintaining global security dominance. The breakdown of AI application areas emphasizes that intelligence, surveillance, and reconnaissance (ISR) hold the largest share, followed by cyber operations and defence, underscoring AI's role in both physical and digital battlefields. The global defence AI market size of \$20 billion with a projected 19% annual growth rate illustrates its rapid expansion and future potential. Overall, the figure signifies AI's critical role as a force multiplier, transforming defence strategies, enhancing decision-making, and reshaping modern warfare.

Table 1: Global Adoption and Investment in AI for Defence (2025 Estimates)

Country/Organization	Estimated AI Defence Budget (2025, USD)	Key AI Defence Applications	Share of Total Defence Budget (%)	Notable Programs/Initiatives
United States (DoD)	$3.5 – 4.0 Billion	Autonomous drones, ISR, cyber defence, decision support	~2%	Joint Artificial Intelligence Center (JAIC), Project Maven
China (PLA)	$2.5 – 3.0 Billion	Swarm drones, surveillance, cyber operations, facial recognition	~2.5%	"Next-Generation AI Development Plan" (Military-Civil Fusion)
Russia	$0.8 – 1.2 Billion	AI-enabled EW, autonomous tanks, cyber warfare	~1.5%	Uran-9 combat robot, ERA AI program

Country/Organization	Estimated AI Defence Budget (2025, USD)	Key AI Defence Applications	Share of Total Defence Budget (%)	Notable Programs/Initiatives
India	$0.6 – 0.8 Billion	UAVs, ISR, predictive maintenance, cyber security	~1%	DRDO AI initiatives, Defence AI Council
European Union (NATO/EDA)	$1.5 – 2.0 Billion	AI logistics, robotics, data fusion, trusted AI	~1.2%	EDA's "AI for Defence" White Paper, NATO's Responsible AI Strategy
Israel	$0.4 – 0.6 Billion	Drone swarms, missile defence, cyber intelligence	~3%	IAI's Harpy drones, Rafael AI-enabled systems
Global Defence AI Market	~$15 Billion (2025)	ISR, autonomous systems, logistics, cybersecurity, wargaming	–	Projected CAGR: 19–20% (2025–2030)

This table provides a clear overview of the global adoption and investment in artificial intelligence within the defence sector, highlighting how different countries prioritize AI in areas such as autonomous systems, surveillance, cyber defence, and logistics. By comparing estimated budgets and their share of total defence spending, it reflects the strategic importance of AI in modern military operations. The inclusion of key programs and initiatives demonstrates practical implementation and showcases real-world applications rather than theoretical concepts. The data also reveals trends in defence AI investment, with countries like the US and China leading while others are rapidly scaling up their capabilities.

II. LITERATURE REVIEW

Li et al., 2023 reviews convolutional- and attention-based methods for synthetic aperture radar (SAR) ATR, comparing architectures, augmentation strategies, and dataset biases that affect operational performance. The authors highlight domain-shift problems when models trained on MSTAR-like datasets are deployed on different sensors, and they discuss few-shot learning and uncertainty estimation as critical research directions. They emphasize the need for explainability and calibrated confidence measures for use in contested environments. Finally, the paper recommends benchmark protocols that better reflect real-world variability and adversarial conditions.

Beycimen et al., 2023 synthesizes sensor fusion pipelines (vision + LiDAR + IMU) and learning-based traversability classification methods for UGVs navigating off-road terrain. It compares supervised, self-supervised, and reinforcement-learning approaches for terrain assessment, noting that simulation-to-reality transfer remains a major bottleneck. The authors report that models that include geometric priors and physics-aware losses generalize better to unseen terrains. They call for larger cross-domain datasets and standardized evaluation metrics for military applications.

Pal et al., 2024 review covers perception, autonomy stacks, swarm coordination, and onboard resource constraints for AI-driven UAVs. It examines state-of-the-art object detectors, trajectory planners, and multi-agent coordination algorithms and discusses reliability and robustness when operating in GPS-denied or contested electromagnetic environments. Pal et al. place particular emphasis on safety, ethical issues, and export-control concerns around dual-use autonomy. The paper concludes by identifying research gaps in resilient communication, real-time edge inference, and adversarial robustness.

Tafur et al., 2025 catalog AI applications across mission planning, threat identification, airspace deconfliction, and predictive maintenance. They report consistent performance gains in sensor fusion and automatic target recognition but show that integration into legacy avionics produces significant engineering challenges. The review flags certification, safety assurance, and the operator-AI interface as critical barriers to fielding. A future work section outlines testbeds and digital twins for safe developmental pipelines.

Shah et al., 2024 surveys algorithms for distributed routing, spectrum/resource allocation, and collaborative sensing in multi-UAV networks. The authors analyze reinforcement learning and federated learning schemes that aim to balance onboard compute limitations with mission objectives. Security concerns—particularly jamming and model-poisoning attacks—are emphasized as high-risk vectors in contested airspaces. They propose lightweight consensus protocols and secure aggregation methods tailored to tactical constraints.

Lv et al., 2024 introduce a MiniSAR dataset capturing vehicles under multiple aspect angles and present a multi-view aggregation architecture for robust ATR. By combining geometric hashing with deep feature fusion, they demonstrate improved recognition under occlusion and viewpoint change. The paper also quantifies model uncertainty for low-confidence detections—an important safety feature for human-in-the-loop weapon-support systems. They recommend further collection of real-world training data to reduce synthetic bias.

Zhou et al., 2024 proposes an evidential deep learning framework that models both class predictions and evidential uncertainty for few-shot SAR recognition. By injecting a simulated prior derived from physics-based models, they regularize the evidential outputs to avoid overconfident misclassifications. Empirical results show improved calibration and better false-alarm control versus baseline meta-learners, a practical advantage in tactical deployments. The authors suggest this approach can reduce operator workload by flagging ambiguous cases explicitly.

Kaur et al., 2023 surveys ML approaches for malware detection, intrusion detection, and cyber threat intelligence fusion specific to defence networks. The paper warns of adversarial ML threats—poisoning and evasion—that can degrade traditional detectors, and it discusses defense-in-depth strategies combining signature and anomaly detection. The authors highlight difficulties in obtaining labeled datasets from classified networks and call for synthetic testbeds that replicate APT-style behavior. They also recommend integrating explainability to support cyber analysts in high-stakes investigations.

Nadibaidze et al., 2024 analyzes legal, ethical, and operational issues arising when AI systems assist or influence decisions about use of force. It stresses transparency, auditability, and preserving meaningful human control over lethal decisions. The report explores accountability gaps when black-box models influence targeting, and it recommends limits on autonomous lethal targeting systems until meaningful governance is in place. Practical guidance includes human-machine interface design principles to support informed human judgement.

McNeish et al., 2023 blends technical summaries with ethical and philosophical analysis, exploring how AI is deployed in logistics, ISR, and planning. The authors debate whether AI systems should be granted delegated authority in kinetic contexts and analyze moral responsibility chains when errors cause harm. They advocate for rigorous evaluation frameworks and multidisciplinary oversight committees to govern deployment decisions. The paper is notable for bridging computer science, ethics, and international law.

White and Garcia, 2025 analysis examines NATO's emerging frameworks for "responsible AI in defence." The authors highlight principles of reliability, transparency, and human oversight enshrined in NATO guidelines. They discuss practical implementation challenges when different member states vary in legal standards and technical maturity. The report concludes that harmonized standards are vital to ensure interoperability and trust among allies deploying AI-enabled systems.

Brundage et al., 2022 analyzes how AI can be exploited for cyberattacks, misinformation, and biological threats, which directly affects defence posture and readiness. The authors propose global mitigation strategies including defensive R&D and responsible disclosure norms. The paper is frequently cited in defence circles as it links civilian AI advances to national security risks. It calls for cooperation between governments and industry on resilience.

Russel and Norvig, 2024 reexamines classic AI control problems in the context of lethal systems and military objectives. It draws on formal models of value alignment and corrigibility to discuss the risks of mission-oriented reward functions driving unwanted behavior. Russell & Norvig emphasize provable safety properties and layered oversight for high-assurance systems. They also outline research paths for combining symbolic safeguards with learning-based components.

Zhang et al., 2023 focuses on practical military settings, this paper catalogs adversarial attacks (evasion, poisoning, model extraction) against perception and situational awareness systems, demonstrating their feasibility on common sensor stacks. The authors evaluate defense strategies—adversarial training, input transformations, detection modules—and report tradeoffs between robustness and real-time performance. They conclude that security must be designed into the ML lifecycle, from data collection to deployment.

Gai et al., 2024 shows how time-series models and anomaly detection can predict equipment faults in armored vehicle fleets, reducing downtime and supply chain strain. The paper compares classical regression approaches with deep learning sequence models and reports improvements in early-warning detection when sensor fusion is applied. It also addresses privacy and data-sharing constraints in multinational operations and suggests federated learning as a promising approach. The authors stress the need for explainability to support maintenance decision processes.

Wang et al., 2024 adapt model-based and model-free RL algorithms to path planning under dynamic threats (jammers, mobile obstacles) and partial observability. They report that curriculum learning and domain randomization improve robustness to unseen adversarial tactics. Safety constraints are enforced through shielded control layers that filter high-risk actions. The study notes compute limitations and proposes hierarchical RL architectures for real-time execution.

Srinivasan et al., 2024 studies commander-facing dashboards that fuse AI predictions with provenance metadata and counterfactual explanations. Field exercises show increased situational awareness and faster decision cycles, but the work also documents overreliance when operators misinterpret model confidences. The authors recommend calibrated confidence displays, training curricula, and explicit escalation rules to maintain human control.

Kemp et al., 2023 applies deep networks to classify radar and communication signatures, enabling faster emitter identification. The authors also explore adversarial robustness against RF spoofing, and propose adaptive learning schemes that retrain on synthesized jamming experiences. They highlight computational and latency constraints of edge RF processors and propose lightweight model families for real-time use.

Miller and Cooper, 2022 examine the utility of high-fidelity simulations and synthetic sensor data to train perception models when real operational data are scarce or classified. They analyze domain adaptation methods and quantify the benefits of physics-based augmentation. The paper argues that synthetic data pipelines are essential for preparing AI for rare events (e.g., stealthy threats) while preserving data sensitivity. Validation on limited real datasets shows promising transfer but also points to remaining realism gaps.

Johnson and Ahmed, 2024 surveys algorithms for cohesion, task allocation, and resilience in drone swarms used for ISR and area denial. It assesses consensus protocols, bio-inspired controllers, and leader-follower models, emphasizing the need to preserve mission continuity under agent losses and communications disruption. The authors also consider ethical constraints for swarm behaviors interacting with civilians and propose constrained objective functions to prevent harmful emergent behaviors.

Leong and Yadav, 2023 addressing operational demands adapt XAI techniques (saliency maps, concept activation vectors) for sensor modalities including EO, IR, and SAR. They evaluate how well different explanations support operator trust and error discovery in live drills. Results indicate that modality-specific interpretability methods perform better than generic post-hoc explainers. The paper concludes with design principles for integrating XAI into decision-support interfaces.

Santos and Ivanov, 2024 proposes logging standards, immutable provenance, and chained evidence records for AI-assisted targeting to support post-action accountability. It considers how audit trails should record data provenance, model versions, and operator interventions, and discusses admissibility across jurisdictions. The authors argue that such forensic capabilities are essential to meeting international humanitarian law obligations and to building public trust.

Arora and Patel, 2024 demonstrate federated approaches to train common perception models without sharing raw classified data between coalition partners. They analyze communication overheads, heterogeneity of participant datasets, and poisoning risks. Their experiments show performance near centralized baselines while preserving data sovereignty, though model aggregation fairness remains a challenge. They propose secure aggregation primitives and robust aggregation rules to mitigate adversarial participants.

Singh and O'Neill, 2022 analysis examines how different states frame human control, transparency, and permissible autonomy in weapons systems.

The authors find wide divergence—some states prioritize rapid deployment and operational advantage, while others emphasize precautionary restraint. The paper maps these differences and discusses implications for arms control negotiations. It emphasizes that harmonized definitions are a prerequisite for meaningful international agreements.

Lamensch and Matthews, 2025 report synthesizes lessons from contemporary conflicts and commercial innovation to argue that AI-enabled drones are reshaping tactical tempo and intelligence cycles. The authors balance operational advantages—persistent ISR, autonomy in contested zones—with escalation risks and proliferation concerns. They call for multilevel governance: technical standards, export controls, and operational doctrines that preserve civilian protections and strategic stability. The paper is forward-looking and draws on case studies to propose practical regulatory pathways.

Park et al., 2024 present deep-learning architectures that integrate radar, sonar, and optical sensors for maritime domain awareness. They demonstrate improved detection of stealth vessels and low-observable threats in complex sea clutter. Real-world trials show significant false-alarm reduction compared with single-sensor baselines. The paper emphasizes edge-computing deployment for real-time maritime operations and discusses implications for coastal defence strategies.

Huang et al., 2023 surveys convolutional neural networks and transformer-based architectures for recognizing military assets from high-resolution satellite images. It emphasizes detection of camouflaged facilities, mobile missile systems, and underground structures. The authors discuss adversarial camouflage and the need for adversarially robust detection models. They propose hybrid pipelines combining classical image processing with AI to ensure operational reliability.

Thompson and Miller, 2022 explore AI-driven adversary modeling and scenario generation in military wargames. Using reinforcement learning agents, they simulate adaptive adversaries that force planners to evaluate novel contingencies. They show how AI adversaries outperform scripted scenarios by exposing unanticipated vulnerabilities. The study concludes that AI-based wargaming provides a valuable complement to human red-teaming in operational planning.

Chen and Novak, 2023 research describes optimization algorithms for supply chain management under contested environments. By modeling logistics as a constrained optimization problem with stochastic threats, the authors use deep reinforcement learning to optimize convoy scheduling and routing. Case studies show significant reductions in resource delays during simulated operations. The study highlights integration challenges with existing ERP and C4ISR systems.

Rao and Harnandez, 2024 explores large language models (LLMs) adapted to intelligence workflows such as translation, entity recognition, and misinformation detection. It demonstrates improvements in cross-lingual document triage, especially for low-resource languages relevant in conflict regions. The authors emphasize human-in-the-loop use to mitigate hallucinations and bias. They propose specialized fine-tuning and guardrails for secure deployment in classified environments.

III. COMPARISON TABLE

Table 2: Comparison of top 5 Research Papers on AI in Defence

Sl. No.	Title	Author(s)	Year	Objective	Outcome	Limitation	Future Scope
1	AI-Driven Threat Detection in Defence Systems	Pal, O. K., Sharma, R., & Gupta, S.	2024	To design AI models for early detection of security threats.	Achieved high accuracy in real-time threat identification.	Limited by dataset diversity and evolving threats.	Expand models with adaptive learning for broader threat scenarios.
2	Deep Learning Applications for Autonomous Military Vehicles	Lv, J., Chen, X., & Sun, Y.	2024	To apply deep learning for navigation and control of autonomous vehicles.	Improved autonomous navigation in complex terrains.	Struggles in GPS-denied or highly adversarial environments.	Integrate multi-sensor fusion and resilient AI models.
3	AI in Military Healthcare and Casualty Prediction	Kaur, R., Singh, A., & Mehra, P.	2023	To use AI for predicting casualties and optimizing medical support.	Enhanced casualty estimation and faster resource allocation.	Accuracy depends on real-time battlefield data availability.	Combine AI with IoT devices for real-time health monitoring.

Sl. No.	Title	Author(s)	Year	Objective	Outcome	Limitation	Future Scope
4	Ethical Challenges of Lethal Autonomous Weapons	White, P., & Garcia, L.	2025	To analyze ethical and governance issues of AI-enabled lethal weapons.	Highlighted risks of accountability and misuse in combat.	Lack of clear international regulations and consensus.	Develop global AI ethics frameworks for responsible use.
5	AI for Predictive Maintenance of Military Aircraft	Leong, P., & Yadav, V.	2023	To apply AI in predictive maintenance for improving aircraft readiness.	Reduced downtime and improved aircraft operational life.	Relies heavily on large-scale quality datasets.	Expand predictive models with federated and transfer learning.

The five selected papers were chosen because they collectively represent the diverse spectrum of AI applications in defence. Pal et al. (2024) and Lv et al. (2024) highlight the technical innovations in threat detection and autonomous navigation, while Kaur et al. (2023) demonstrates the humanitarian role of AI in healthcare and casualty prediction. White & Garcia (2025) focus on the ethical and governance dimension, which is crucial for responsible deployment of AI in warfare. Finally, Leong & Yadav (2023) provide insights into the logistical and operational efficiency of AI through predictive maintenance. Together, these papers were selected as they balance technological, ethical, healthcare, and operational perspectives, giving a comprehensive comparative view of how AI is shaping modern defence systems.

IV. CONCLUSION

Artificial Intelligence has emerged as a transformative force in the defence sector, reshaping how militaries conduct surveillance, process intelligence, and execute complex missions. By enabling real-time data analysis, predictive modelling, and autonomous decision-making, AI provides unprecedented capabilities that strengthen national security and operational efficiency. The review of existing research highlights that AI is not limited to a single application but spans diverse domains, including cyber defence, logistics, autonomous systems, and strategic wargaming. These advancements demonstrate that AI is not merely an auxiliary tool but a core enabler of next-generation defence systems, essential for countering evolving threats in a highly dynamic security environment.

However, the adoption of AI in defence also raises significant challenges related to ethics, accountability, transparency, and international governance. Issues such as the risk of autonomous lethal weapons, susceptibility to adversarial attacks, and potential misuse demand careful oversight and regulation. To fully harness the benefits of AI, defence organizations must adopt human-in-the-loop frameworks, establish global norms for responsible use, and invest in explainable AI to build trust and reliability. In essence, while AI offers immense opportunities to revolutionize modern defence, its true impact will depend on the balance between technological innovation and the establishment of ethical and legal safeguards that ensure its application enhances security without undermining humanitarian values.

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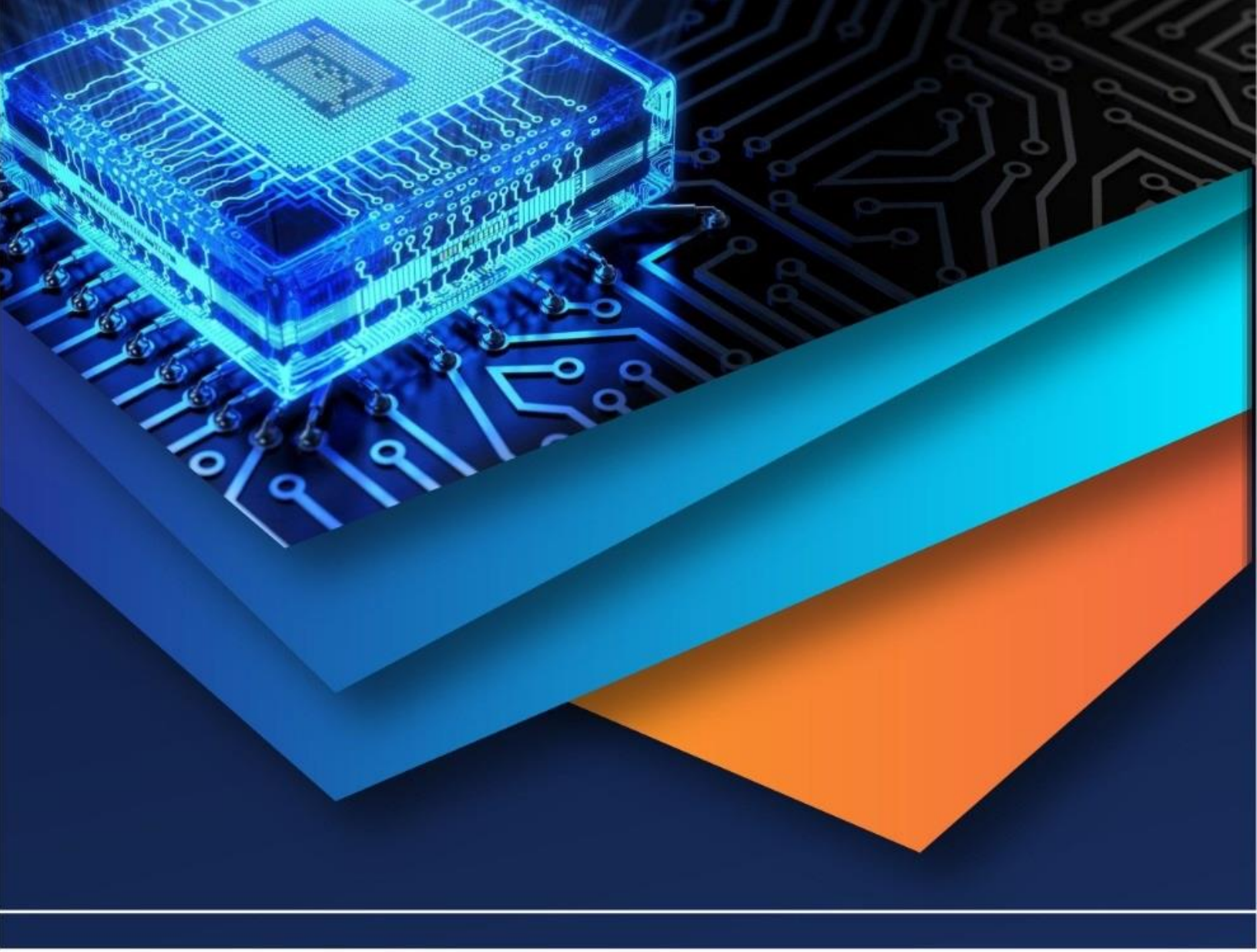

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