CHALLENGES THAT NEW TECHNOLOGIES ARE BRINGING IN FUTURE DEFENCE PLANNING AND MILITARY OPERATIONS

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Abstract: *This paper examines the critical challenges that new technologies bring to future defense planning and military operations. It explores the transformative potential of key emerging technologies, analyzes the planning and integration challenges they present and assesses their impact on battlefield operations. By understanding these challenges, defense establishments can better prepare for a future characterized by rapid technological change and evolving security threats.*

Keywords*: challenges, new technologies, military operations, security threats.*

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1. Introduction

In the rapidly evolving landscape of global security, emerging technologies are fundamentally reshaping defense planning and military operations. The convergence of artificial intelligence, autonomous systems, hypersonic weapons, space-based technologies, quantum computing, directed energy weapons, biotechnology, advanced materials and robotics is creating unprecedented challenges and opportunities for defense establishments worldwide. These technologies are not merely enhancing existing capabilities but are transforming the very nature of warfare, security threats and strategic competition.

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The integration of these emerging technologies into defense frameworks presents multifaceted challenges that span technical, operational, ethical, legal and geopolitical domains. Defense planners must navigate complex issues including budget constraints, technological integration difficulties, ethical considerations and intensifying great power competition. As nations race to harness these technologies for military advantage, the global security landscape is becoming increasingly complex and unpredictable.

The stakes could not be higher. As Austrian Foreign Minister Alexander Schallenberg warned, the rise of AI-enabled weapons systems represents "the Oppenheimer moment of our generation." Just as nuclear weapons redefined warfare in the 20th century, today's emerging technologies are poised to revolutionize military capabilities and operations in the 21st century. How nations respond to these technological challenges will shape the future of global security for decades to come.

2. Emerging Technologies in Defense

The defense landscape is undergoing a profound transformation driven by rapid technological innovation. This section examines key emerging technologies that are reshaping military capabilities and creating new challenges for defense planning and military operations.

2.1 Artificial Intelligence and Autonomous Systems

Artificial intelligence (AI) represents perhaps the most transformative technology in modern defense. AI systems are increasingly capable of processing vast amounts of data, recognizing patterns, making predictions and supporting or even making decisions with minimal human intervention. In military contexts, AI applications range from intelligence analysis and logistics optimization to autonomous weapons systems and battlefield decision support.

The Pentagon is actively testing AI-driven decision-making tools in real-world scenarios, including the use of generative AI tools in the Indo-Pacific region to enhance battlefield decision-making against high-tech adversaries. Companies like Anduril and Palantir are collaborating with defense departments to develop systems that integrate sensor data for real-time decision-making and equip commanders with actionable intelligence across multiple domains.

Autonomous systems, enabled by advances in AI, are becoming increasingly prevalent in military operations. These include unmanned aerial vehicles (UAVs), unmanned ground vehicles (UGVs) and unmanned underwater vehicles (UUVs). The war in Ukraine has demonstrated the growing importance of autonomous systems, with drones now causing approximately 70 percent of battlefield casualties. The evolution of drone

warfare has accelerated, with both sides in the conflict developing countermeasures and counter-countermeasures at unprecedented speed.

2.2 Hypersonic Weapons and Advanced Missile Systems

Hypersonic weapons, capable of traveling at speeds exceeding Mach 5 (five times the speed of sound), are dramatically reducing decision time for defense systems[1]. These weapons combine speed, maneuverability and altitude to evade current missile defense systems, creating new vulnerabilities and challenging traditional deterrence frameworks.

Major powers including the United States, Russia and China are investing heavily in hypersonic technology, creating a new dimension of strategic competition. The development of these weapons is compressing response times for military decision- makers, potentially increasing the risk of miscalculation in crisis situations.

2.3 Space-Based Technologies

Space is increasingly becoming a contested domain, with nations developing capabilities to protect their space assets and potentially threaten those of adversaries. Advanced satellite systems provide critical capabilities for intelligence, surveillance, reconnaissance, communication, navigation and timing. The militarization of space includes the development of anti-satellite weapons, space-based sensors and potentially space-based strike capabilities[2].

The lack of a commonly accepted definition and delimitation of space presents legal challenges for defense planners. While frameworks such as the Outer Space Treaty and the Artemis Accords offer some guidance, significant gaps persist in the regulation of military activities in space.

2.4 Quantum Computing and Advanced Cryptography

Quantum computing represents a revolutionary approach to computation that could break current encryption methods and transform data processing capabilities. Nations are racing to develop quantum computers that could decrypt sensitive communications, potentially rendering current security measures obsolete.

Beyond cryptography, quantum technologies have applications in sensing, timing and navigation that could enhance military capabilities. Quantum sensors could detect submarines or underground facilities, while

[1] Congressional Research Service. (2025). "Hypersonic Weapons: Background and Issues for Congress" April 10, 2025

[2] Arms Control Association. (2005)." Action/Reaction: U.S. Space Weaponization and China", available at https://www.armscontrol.org/act/2005-12/features/actionreaction-us-space-weaponization-and-china, accessed on 10.08.2025.

quantum navigation systems could provide positioning information in GPS-denied environments.

2.5 Directed Energy Weapons

Directed energy weapons, including high-energy lasers and high-power microwave systems, offer the potential for speed-of-light engagement of targets with potentially unlimited magazines. These weapons can counter threats ranging from small drones to missiles and could significantly alter the cost equation of defense by substituting relatively inexpensive energy for expensive kinetic interceptors.

The development of these weapons is advancing rapidly, with several systems already deployed for testing and operational use. However, challenges remain in power generation, beam control and atmospheric propagation.

2.6 Biotechnology and Human Enhancement

Advances in biotechnology are creating new possibilities for enhancing human performance, developing novel materials and potentially creating new biological threats. Military applications include improved medical treatments for battlefield injuries, enhanced soldier performance through genetic or pharmaceutical means and biological sensors for detecting threats.

The global biotechnology market was valued at $1.55 trillion in 2023 and is projected to reach $3.88 trillion by 2030, indicating the scale of investment and potential impact of this technology. However, biotechnology also raises significant ethical and security concerns, including the potential for misuse in biological warfare.

2.7 Advanced Materials and Nanotechnology

Nanotechnology and advanced materials science are enabling the development of stronger, lighter and more capable materials for military applications[3]. These include super-strong materials for armor using tungsten and carbon nanotubes, "electrochromic camouflage" allowing fabric colors to change instantly to blend with surroundings and fabrics embedded with nanowires and hydrogels to enhance soldier protection and performance.

The Department of Defense has identified nanotechnology as one of six "Strategic Research Areas" and invests hundreds of millions of dollars annually in related research. Applications span from personal protection to stealth technologies, medical applications and enhanced surveillance capabilities.

[3] Available at https://www.defensemagazine.com/article/another-potential-aspect-of-the-military-revolution-nanotechnology-as-a-key-element-of-natos-future, accessed on 10.08.2025.

2.8 Robotics and Unmanned Systems

Military robotics have evolved dramatically since the first "teletanks" operated by radio signals in World War II. Today's military robots include transportation robots, search and rescue robots, mine clearance robots, firefighting robots, surveillance robots, armed robots and training robots. These systems can work continuously without rest, protect human life by performing hazardous tasks and reduce labor-intensive operations.

The integration of robotics with AI is creating increasingly autonomous systems capable of complex missions with minimal human supervision. This evolution raises important questions about the appropriate level of human control and the ethical implications of delegating lethal force decisions to machines.

The convergence of these technologies is creating new capabilities and challenges that defense planners must address. As these technologies continue to evolve and interact, they will fundamentally reshape the character of warfare and the nature of military operations in the coming decades.

3. Challenges in Defense Planning

The integration of emerging technologies into defense frameworks presents multifaceted challenges for military planners and policymakers. This section examines the key challenges in defense planning related to these technologies.

3.1 Budget Constraints and Investment Prioritization

Despite increasing defense budgets in many countries, the costs associated with developing and deploying emerging technologies create significant financial challenges. The United States committed more than $150 billion to research, development, testing and evaluation (RDT&E) in fiscal year 2024, marking a 55 percent expansion of defense funding during the past five years. NATO established a €1 billion Innovation Fund, the first multinational venture capital initiative in defense technology[4]. However, these investments, while substantial, must be carefully allocated across competing priorities.

Defense planners face difficult decisions about which technologies to prioritize and how to balance investment across different stages of technological maturity. As identified by McKinsey, technologies can be categorized into three distinct stages:

a) **Emerging Innovation**: Capital-intensive technologies with

[4] Available at https://www.nato.int/cps/en/natohq/news_217864.htm, accessed on 11.08.2025.

higher risk and long development horizons that often lack commercial incentives.

b) **Maturing Technology**: Innovations with growing technical proof points that are not yet scaled or prepared for defense applications.
c) **Scalable Capabilities**: Mature defense-ready technologies that need to be adopted at scale to achieve full impact.

Balancing investments across these categories requires strategic foresight and careful planning. The challenge is compounded by the rapid pace of technological change, which can render expensive systems obsolete before they are fully deployed.

3.2 Integration with Existing Systems and Doctrine

Defense organizations often struggle with integrating new technologies into entrenched processes given their size and complexity[5]. Legacy systems, designed and built for different operational environments, may be incompatible with emerging technologies. The challenge extends beyond technical integration to include doctrinal adaptation, organizational restructuring and cultural change.

Military doctrine, developed over decades, must evolve to incorporate new technological capabilities. This requires not only technical understanding but also conceptual innovation in how military forces organize, train and fight. The integration of AI, autonomous systems and other emerging technologies demands new operational concepts that may challenge traditional hierarchical command structures and decision- making processes.

3.3 Ethical and Legal Considerations

Emerging technologies raise profound ethical and legal questions that defense planners must address. The development and deployment of autonomous weapons systems, for example, raises concerns about human control, accountability and the potential for unintended escalation.

Current legal frameworks have significant voids, such as binary conceptualizations of war and peace and combatant and noncombatant. The IT Army of Ukraine, a volunteer organization crowdsourcing cyber warfare, illustrates this challenge. The demarcation of these individuals as combatants or noncombatants is ambiguous due to factors such as their location across the world and volunteer status[6].

[5] Available at https://www.mckinsey.com/industries/aerospace-and-defense/our-insights/-creating-a-modernized-defense-technology-frontier/, accessed on 11.08.2025.
[6] Available at https://www.cmu.edu/cmist/news-events/news/2025/march/when-technology-transforms-war-legal-and-ethical-considerations.html, accessed on 11.08.2025.

International humanitarian law typically develops in response to war stimuli, creating a lag between technological innovation and legal frameworks. Defense planners must navigate this uncertain legal terrain while ensuring that military operations comply with existing laws and ethical norms.

3.4 Geopolitical Competition and Strategic Stability

Emerging technologies are transforming the global defense landscape, with increasing geoeconomic tensions and evolving security threats. Rising competition in technology is driving up defense budgets and mobilizing defense innovators across sectors[7]. Major powers, including the United States, China and Russia, are seeking to rapidly modernize their defense capabilities across multidomain operations.

The strategic calculus of revealing or concealing disruptive military capabilities adds another layer of complexity. Nations selectively disclose advanced capabilities to gain strategic advantages and compel rival nations to recalibrate their military assessments. This dynamic can lead to misperceptions, miscalculations and potential escalation.

Hypersonic weapons, AI-powered systems and other emerging technologies are not just tools of war but instruments of influence, reshaping perceptions of military power and altering the global balance of power. Defense planners must consider how these technologies affect deterrence, strategic stability and the potential for arms races.

3.5 Technological Uncertainty and Rapid Change

The rapid pace of technological change creates significant uncertainty for defense planners. Technologies that seem promising may fail to deliver expected capabilities, while unexpected breakthroughs can disrupt carefully crafted plans. The long timelines of defense acquisition programs clash with the accelerating pace of technological innovation, creating a persistent gap between state-of-the-art technology and deployed military systems.

Defense planners must develop more agile approaches to technology development, acquisition and deployment. This may include greater use of prototyping, experimentation and spiral development processes that allow for continuous adaptation and improvement.

3.6 Workforce and Expertise Challenges

The development and deployment of emerging technologies require specialized expertise that is often in short supply within military organizations. Defense establishments compete with the private sector for

[7] Available at https://www.mckinsey.com/industries/aerospace-and-defense/our-insights/-creating-a-modernized-defense-technology-frontier/, accessed on 12.08.2025.

talent in areas such as AI, quantum computing and cybersecurity, often at a disadvantage in terms of compensation and work environment.

Building and maintaining the necessary technical expertise requires new approaches to recruitment, education, training and retention. It also demands new partnerships with academia, industry and international allies to access specialized knowledge and capabilities.

3.7 Fragmentation of the Defense Ecosystem

The defense ecosystem is increasingly fragmented across various players, including venture capital firms, startups, government laboratories, allied innovation units and the traditional defense industrial base. This fragmentation can impede collaboration and coordination, making it difficult to achieve at-scale adoption of emerging technologies.

With increasingly open customers keen on modernizing, real opportunity remains within this fragmented ecosystem to lead collaboration toward achieving at-scale adoption.

These actors stand to gain immensely by reshaping defense capabilities, developing what McKinsey calls a "modernized defense frontier"–a foundation for Western security.

Addressing these challenges requires a comprehensive approach that spans technological, organizational, ethical, legal and strategic dimensions. Defense planners must develop new frameworks, processes and partnerships to harness the potential of emerging technologies while mitigating the risks they pose.

4. Impact on Military Operations

The integration of emerging technologies is fundamentally transforming military operations across all domains. This section examines how these technologies are reshaping the battlefield and creating new operational challenges and opportunities.

4.1 Transformation of Battlefield Operations

Emerging technologies are dramatically altering the character of warfare. AI and autonomous systems are accelerating the pace of operations, compressing decision cycles and enabling new forms of distributed, networked warfare. The battlefield of the future will be characterized by[8]:

Accelerated Decision-Making

AI is reshaping warfare by accelerating decision-making processes. The Pentagon is actively testing AI-driven decision-making tools in real-world scenarios, including the use of generative AI in the Indo-Pacific

[8] Available at https://www.armyupress.army.mil/Journals/Military-Review/English-Edition-Archives/May-June-2024/MJ-24-Glonek/, accessed on 12.08.2025.

region. Companies like Anduril and Palantir are developing systems that integrate sensor data for real-time decision-making and equip commanders with actionable intelligence across multiple domains.

This acceleration of decision-making creates both opportunities and risks. While faster decisions can provide tactical advantages, they also increase the potential for errors, misinterpretation and unintended escalation. The compression of decision cycles may eventually exceed human cognitive capabilities, raising questions about the appropriate balance between human and machine decision-making in combat.

Autonomous and Unmanned Systems Proliferation

The proliferation of autonomous and unmanned systems is changing the composition of military forces and the conduct of operations. Drones and other unmanned systems reduce risk to human operators, can operate continuously without rest and can access areas that would be too dangerous or difficult for humans.

The war in Ukraine demonstrates the growing importance of these systems, with drones now causing approximately 70 percent of battlefield casualties. Both Ukraine and Russia are locked in an AI-driven drone race, with both sides leveraging autonomous technologies to gain an edge on the battlefield. As electronic warfare capabilities advance—jamming drones as a result—both sides are pushed to innovate at an accelerated pace[9].

The next phase of drone warfare is taking shape with AI-powered targeting systems designed to operate even in heavily jammed environments, allowing drones to identify and strike targets with minimal human intervention. This evolution could potentially turn warfare into a battle of algorithms, where the side with the fastest and most adaptive AI will dominate.

Multi-Domain Operations

Emerging technologies are enabling more effective integration of operations across land, sea, air, space and cyberspace. AI-driven data fusion systems equip commanders with actionable intelligence across multiple domains. By integrating vast amounts of data from these domains, these systems enable real-time decision-making, enhance battlefield awareness and ensure a synchronized response across complex operational environments.

This integration creates new opportunities for coordinated effects but also increases complexity and potential vulnerabilities. Disruption in one domain can have cascading effects across others, requiring new approaches to resilience and redundancy.

[9] Available at https://www.lawfaremedia.org/article/how-will-artificial-intelligence-impact-battlefield-operations, accessed on 13.08.2025.

Changing Nature of Military Advantage

The sources of military advantage are shifting from traditional factors like mass and firepower to information superiority, technological edge and decision speed. This shift has several important implications:

Information Dominance

Information is becoming the critical resource in modern warfare. The ability to collect, process, analyze and act on information faster and more effectively than adversaries provides a decisive advantage. AI and advanced analytics enable the processing of unprecedented volumes of data, turning raw information into actionable intelligence.

As one expert noted regarding the war in Ukraine, "Over the past three years, an enormous amount of data has been collected—equivalent to hundreds of years' worth— spanning air, space, ground and cyber-based sources. Both belligerents are already utilizing this data, shaping military planning and wargaming, particularly in the use of drones and unmanned systems".[10]

Asymmetric Capabilities

Emerging technologies are enabling new forms of asymmetric warfare, where relatively small or less-resourced actors can challenge larger, more powerful adversaries. Low-cost drones, cyber capabilities and other technologies provide options for asymmetric strategies that can offset traditional military advantages.

This democratization of advanced capabilities is changing the strategic calculus for major powers and creating new security challenges. Non-state actors and smaller nations can now access technologies that were previously the exclusive domain of major military powers.

Human-Machine Teaming

The integration of humans and machines in military operations is creating new capabilities and challenges. Human-machine teaming combines the judgment, adaptability and ethical reasoning of humans with the speed, precision and endurance of machines.[11]

Effective human-machine teaming requires new approaches to training, organization and command and control. It also raises questions

[10] Available at https://www.lawfaremedia.org/article/how-will-artificial-intelligence-impact-battlefield-operations, accessed on 14.08.2025.

[11] Available at https://warontherocks.com/2024/11/mastering-human-machine-warfighting-teams/, accessed on 16.08.2025.

about the appropriate division of responsibilities between humans and machines, particularly in high-stakes decisions involving the use of lethal force.

4.2 Operational Challenges

The integration of emerging technologies into military operations creates several significant challenges:

Vulnerability to New Forms of Attack

As military forces become more dependent on advanced technologies, they also become vulnerable to new forms of attack. Cyber operations, electronic warfare, anti-satellite weapons and other capabilities can target the technological foundations of modern military power.

The development of countermeasures and counter-countermeasures is accelerating, creating a continuous cycle of technological competition. For example, as Russia advanced its electronic warfare capabilities to jam Ukrainian drones, both sides were pushed to innovate, leading to the adoption of fiber-optic cables to bypass jamming, followed by countermeasures to disrupt these cables.

Complexity and Interoperability

The increasing complexity of military systems and the challenge of ensuring interoperability across different platforms and between allies create significant operational challenges. Legacy systems may be incompatible with new technologies and different systems may use different data formats, communication protocols and operating procedures.

Addressing these challenges requires common standards, interfaces and architectures, as well as new approaches to system design and integration. It also demands greater collaboration between different military services and between nations.

Training and Readiness

Emerging technologies require new approaches to training and readiness. Military personnel must develop new skills and competencies to effectively employ advanced systems and to operate in technology-intensive environments.

Simulation, virtual reality and augmented reality technologies offer new opportunities for realistic, cost-effective training. AI can provide personalized training experiences and assess performance in ways that were not previously possible. However, these approaches must be balanced with traditional training methods that develop essential military skills and values.

4.3 Ethical and Legal Implications for Operations

The operational use of emerging technologies raises important ethical and legal questions:

Rules of Engagement

Traditional rules of engagement may be inadequate for operations involving autonomous systems, AI and other emerging technologies. Military commanders and policymakers must develop new rules that address questions of human control, accountability and proportionality in the use of force.

These rules must balance operational effectiveness with ethical and legal constraints, ensuring that military operations comply with international humanitarian law and other relevant legal frameworks.

Attribution and Accountability

Emerging technologies can complicate attribution and accountability for military actions. Cyber operations, for example, can be difficult to attribute to specific actors, while autonomous systems raise questions about who is responsible for decisions made by machines.

Clear chains of command, robust oversight mechanisms and appropriate legal frameworks are essential to ensure accountability for the use of emerging technologies in military operations.

The impact of emerging technologies on military operations is profound and far-reaching. These technologies are not simply enhancing existing capabilities but are transforming the fundamental nature of warfare. Military organizations must adapt their doctrine, organization, training and operations to harness the potential of these technologies while addressing the challenges they create.

5. Conclusions

The rapid advancement of emerging technologies is fundamentally reshaping the landscape of defense planning and military operations. As this paper has explored, technologies such as artificial intelligence, autonomous systems, hypersonic weapons, space-based technologies, quantum computing, directed energy weapons, biotechnology, advanced materials and robotics present both unprecedented opportunities and formidable challenges for defense establishments worldwide.

The challenges facing defense planners are multifaceted and complex. Budget constraints require difficult decisions about investment prioritization across emerging, maturing and scalable technologies. Integration challenges arise when attempting to incorporate new technologies into existing systems and doctrines. Ethical and legal considerations demand careful attention as technologies like autonomous weapons systems raise profound questions about human control and accountability. Geopolitical competition intensifies as nations race to achieve technological superiority, potentially destabilizing strategic

relationships. Technological uncertainty, workforce expertise gaps and ecosystem fragmentation further complicate the planning landscape.

On the operational front, emerging technologies are transforming battlefield dynamics through accelerated decision-making cycles, proliferation of autonomous systems and the integration of operations across multiple domains. The nature of military advantage is shifting toward information dominance, asymmetric capabilities and effective human-machine teaming. New vulnerabilities, increased complexity and evolving training requirements create additional operational challenges. Meanwhile, traditional rules of engagement and accountability frameworks struggle to address the unique characteristics of technology-enabled warfare.

As Austrian Foreign Minister Alexander Schallenberg warned, we are experiencing "the Oppenheimer moment of our generation." The comparison to nuclear weapons is apt— just as nuclear technology fundamentally altered the strategic landscape of the 20th century, today's emerging technologies are poised to transform warfare in the 21st century. However, there is a critical difference: while nuclear weapons represented a single, albeit revolutionary, technology, today's defense establishments must contend with multiple rapidly evolving technologies that interact in complex and often unpredictable ways.

Looking ahead, several imperatives emerge for defense planners and military leaders:

a) ***Develop adaptive planning frameworks*** that can accommodate technological uncertainty and rapid change. Traditional linear planning processes must give way to more agile, iterative approaches that allow for continuous learning and adjustment.

b) ***Foster closer collaboration across the fragmented defense ecosystem***, including government agencies, traditional defense contractors, technology companies, startups, research institutions and international allies. No single organization possesses all the expertise and resources needed to address these challenges.

c) ***Invest in human capital by recruiting, training and retaining personnel*** with the technical expertise and adaptive thinking skills needed to harness emerging technologies effectively. The human dimension remains critical even as technology advances.

d) ***Establish ethical and legal frameworks*** that can guide the development and use of emerging technologies in ways that align with national values and international norms. These frameworks must evolve alongside technological capabilities.

e) ***Balance technological innovation with operational effectiveness*** by ensuring that new technologies enhance rather than complicate military operations. The ultimate measure of success is not technological sophistication but improved operational outcomes.

The challenges posed by emerging technologies in defense planning and military operations are daunting, but they also present opportunities to enhance security, reduce risks to military personnel and potentially create more precise and discriminate military capabilities. By understanding these challenges and developing comprehensive approaches to address them, defense establishments can navigate the complex technological landscape and prepare for an uncertain future.

As we stand at this technological inflection point, the decisions made today about how to develop, integrate and employ emerging technologies will shape the security environment for decades to come. The stakes could not be higher and the need for thoughtful, informed approaches to these challenges has never been more urgent.

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