

Emerging Military Technologies

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ABSTRACT

The defense sector is at the forefront of technological innovation, driven by the need to maintain military superiority and safeguard national security. The global military apparatus is witnessing significant transformations and leveraging technology trends to strengthen capabilities. Emerging military technology trends are changing the battlefield in four aspects—connectivity, lethality, autonomy, and sustainability. Members of Congress and Pentagon officials are increasingly focused on developing emerging military technologies to enhance US national security and keep pace with US competitors. This paper provides an overview of some of the most prominent emerging disruptive technologies in the defense sector. It presents some selected emerging military technologies in the United States, China, and Russia: artificial intelligence, robotics and autonomous weapons, Internet of things, additive manufacturing, biotechnology, big data analytics, and quantum computing. These technologies are being applied to military use, with potentially far-ranging consequences.

KEYWORDS: *emerging technologies, military, defense, artificial intelligence*

INTRODUCTION

We live in the digital age where everything is touched and connected by technology. Our homes, our cars, and our jobs are all connected to technology. Modern societies are increasingly dependent on technology. Technology is everywhere. It surrounds every aspect of 21st-century life. It is in the cell phones we use, the cars we drive, and even the food we eat. Technology has spanned the globe, connecting devices and people of all nations. It has become integrated into personal, professional, and social aspects of our lives. It is getting better, smaller, and faster. It is becoming more and more in demand in every sector of the economy, particularly in the military. The pace of change in military technology is unprecedented, but human nature does not change at these technological timescales.

The defense sector is constantly evolving, driven by technological advancements and the need to adapt to emerging threats. Crucial objectives for militaries include protecting forces, increasing situational awareness, reducing soldiers' workload, and facilitating movement in challenging terrains.

An emerging technology may be regarded as an enhanced or completely new technology that brings about a radical change. NATO expects four core characteristics to define many key advanced military technologies [1]:

- *Intelligent* – Solutions will exploit integrated AI, knowledge-focused analytic capabilities and symbiotic AI-human intelligence, resulting in the spread of disruptive applications across the technological spectrum.
- *Interconnected* – Solutions will take advantage of the growing network of virtual and physical domains. Connectivity solutions address concerns about how combatants detect and locate their adversaries, communicate with each other, and direct operations. This will include networks of sensors, organizations, individuals and autonomous agents, linked via new encryption methods and distributed ledger technologies.
- *Distributed*: Solutions will employ decentralised and ubiquitous large-scale sensing, storage, and computation to achieve new disruptive military effects.

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- *Digital*: Solutions will blend human, physical and information domains to support novel disruptive effects.

WHAT ARE EMERGING TECHNOLOGIES?

Technology may be regarded as a collection of systems designed to perform some function. It can help alleviate some of the challenges facing business today. Emerging technology is a term generally used to describe new technology. The term often refers to technologies currently developing or expected to be available within the next five to ten years. Any imminent, but not fully realized, technological innovations will have some impact on the status quo.

Emerging technologies are shaping our societies. They continue to affect the way we live, work, and interact with one another. Emerging technology (ET) lacks a consensus on what classifies them as “emergent.” It is a relative term because one may see a technology as emerging and others may not see it the same way. It is a term that is often used to describe a new technology. A technology is still emerging if it is not yet a “must-have” [2]. An emerging technology is the one that holds the promise of creating a new economic engine and is trans-industrial. ET is used in different areas such as media, healthcare, business, science, education, or defense.

The characteristics of emerging technologies include the following [3]:

- *Novelty*: Emerging technologies are typically new or novel, meaning they have yet to be widely adopted or used. They often represent a significant departure from existing technologies or processes.
- *Potential for Disruption*: Emerging technologies have the potential to disrupt existing markets, industries, or ways of doing things. They may also displace existing businesses or industries.
- *Uncertainty*: Because emerging technologies are still in the early stages of development, there is often a high uncertainty surrounding their future potential and impact. It can be challenging to predict how they will evolve.
- *Rapid Change*: Emerging technologies often evolve rapidly, with new developments and innovations emerging frequently. It can make keeping up with the latest trends and advancements challenging.
- *Interdisciplinary*: Emerging technologies often involve multiple disciplines or fields of study, such as computer science, engineering, and biology. They may require collaboration across different fields and industries to develop their potential fully.

Emerging technologies are worth investigating. They are responsible for developing new products or devices. The military often looks to emerging technologies for new services or tools that will help them create a competitive business advantage.

EMERGING MILITARY TECHNOLOGIES

Emerging military technologies are rapidly changing defence sector. These technologies include the following [2,4]:

1. *Artificial Intelligence (AI)*: AI is rapidly transforming the defense sector, offering enhanced capabilities when it comes to autonomous systems, data analysis, and decision-making. In some contexts, militaries will use AI to reduce the scope for human error in military exercises by automating processes. AI will play a key role in defense sector infrastructure. It will leverage predictive capabilities to manage maintenance for military assets, direct technology development, and assist with product testing. AI is currently being incorporated into a number of military applications by both the United States and its competitors. In military and defense, AI adoption enhances computational reasoning for intelligence, surveillance, and reconnaissance missions. This advancement empowers autonomous weapon systems and ensures equipment safety, thereby reducing soldier casualties.
2. *Robotics and Autonomous Weapons Systems*: These are possibly the most controversial technological defense sector development for quite some time. The debate over autonomous weapons systems and the extent to which they should be independent of human intervention is still a major sticking point. The systems allow for the removal of human agency from decision-making processes, but they also possibly open the door to a new, less transparent, and less accountable form of warfare. Robotics and autonomous weapon systems improve the combat effectiveness of the military as well as impact other trends in the industry. Drones, a part of this system, enhance battlefield situational awareness. Multi-mission autonomous military vehicles are instrumental in landmine clearance, search and rescue operations, explosive ordnance disposal, and logistics support. Robots also have capabilities that humans do not have: the ability to stay awake 24/7, the ability to see from all angles, the ability to process information in an instant, etc. Robotic dogs are being used alongside Air Force service members. Figure 1 shows an autonomous weapons system [5].

3. *Internet of Things (IoT)*: The emergence of the IoT as a network of interconnected devices that can exchange data and perform tasks without human intervention will generate vast amounts of valuable data. This will provide militaries with greater insight into operational environments, capabilities, and performance. Technologies like wearable devices, sensors, and drones can all feed back insights, resulting in a more complex and comprehensive account of what is happening on the ground in any given location. There is a substantial rise in the use of the IoT technologies such as sensors, wearables, and edge computing. IoT applications in defense connect ships, planes, tanks, drones, soldiers, and operating bases into a cohesive network. This connection enhances perception, field understanding, situational awareness, and response time. Sensing and computing devices, worn by soldiers and embedded in their equipment, collect a variety of biometric data in the Internet of military things (IoMT) framework.
4. *Cybersecurity*: This is the protection of cyberspace from malicious attack. It has become a major national security priority. Secure operations in cyberspace has become essential for the continued functioning of the international economy. An extraordinary tool for many purposes, the Internet is also vulnerable to attack by hostile intruders, whether to spread misinformation, disrupt vital infrastructure, or steal valuable data. As digital connectivity increases, the defence sector faces an ever-growing threat from cyberattacks. Disruptive technologies in cybersecurity include advanced encryption methods, blockchain technology for secure data sharing, and artificial intelligence-based threat detection systems. Vulnerability to cyber-attacks is a significant concern for military systems, as it could lead to the loss of classified information and damage to systems. Prescriptive security technology, utilizing cybersecurity, AI, and automation, detects potential threats and neutralizes them before they impact defensive cyber warfare capabilities. Advanced firewalls and intrusion detection systems play a crucial role in protecting sensitive military data and ensuring the integrity and security of military operations. As shown in Figure 2, cyber attacks are borderless [6].
5. *3D printing*: Improving performance in speed, capacity, and fuel consumption is crucial, and reducing the weight of defense equipment plays a significant role in this. 3D printing, also known as additive manufacturing, enables the production of components and parts using less material than traditional methods. It employs computer-aided design and computer-aided manufacturing capabilities to create objects through deposition, or layer-by-layer printing. It could transform the way we think about defense-sector supply chains and logistics. It allows for rapid prototyping, on-demand production of spare parts, and equipment customization. The technology reduces the time and cost required for manufacturing, increases flexibility and enables the production of complex geometries that are difficult to achieve through traditional manufacturing processes. It enables localized, on-demand production, thereby reducing the logistical burden. The US Navy is utilizing additive printing to ease supply chain issues. Figure 3 displays how 3D printing is used by the military [7].
6. *Quantum Computing*: This is arguably the technology that has had the least impact on the defense sector. Quantum technology has not yet reached maturity. It has the potential to revolutionize cryptography and computational power. Quantum technology leverages unique quantum physics properties for potentially major improvements in cryptography, computing, sensing and communication security – all crucial for military operations. Quantum computers can solve complex problems exponentially faster than traditional computers and are extremely sensitive to environmental changes, ensuring they offer a significant advantage in target identification, weather forecasting, and data analysis. Quantum technology could have other military applications, such as quantum sensing, which could theoretically enable significant improvements in submarine detection, rendering the oceans “transparent.” Quantum computing may allow adversaries to decrypt information, which could enable them to target US personnel and military operations. Quantum computing, applied in cryptanalysis and simulations, aids informed decision-making. Quantum technology may be far from making sizable impacts within military application, but its implications could be tremendous in terms of sensing, encryption, and communication.
7. *Biotechnology*: This leverages life sciences for technological applications. A number of developments in biotechnology hold potential implications for national security. In the US, unclassified use of biotechnology (i.e. using life sciences to support technological applications)

has been confined to improving military readiness, resiliency, and recovery. The US has also sought applications that would improve soldier strength, cognition, and endurance that would give them leverage over other humans. Only the weaponization of biotechnology is barred by international law.

8. *Immersive Technologies:* Building replicable and flexible experiences becomes easier with immersive technologies, especially for flight or combat training. Augmented reality (AR) goes beyond virtual reality (VR) in military training opportunities. It equips on-field soldiers with wearable glasses or AR headsets, providing mapping information, movement markers, and other data. This technology enhances real-time decision-making for ground forces. In addition to these, immersive technologies assist in mission planning.
9. *Big Data:* In the evolving landscape of warfare, the role of data and its analysis is becoming increasingly crucial. Harnessing big data analytics, militaries unlock insights from diverse data sources, gaining a strategic edge. Efficient interpretation of data from the Internet of military things (IoMT) is another benefit of analytics.
10. *5G Connectivity:* In military operations, the importance of timely and appropriate information is paramount. Accelerating real-time decision support, 5G offers hyper-converged connectivity and secure data networks. 5G networks enable the transfer of vast data amounts to remote sensors and weapons, creating dense, resilient battlefield networks. It also ensures efficient remote control by offering seamless connectivity for unmanned systems, including drones and autonomous vehicles.
11. *Blockchain:* Data security is a crucial aspect of data sharing, and blockchain technology addresses this need effectively. Defense companies are developing solutions based on blockchain to safeguard confidential military data and combat cyber threats. This technology finds use in device tracking, procurement process streamlining, and supply chain security. Blockchain technology also ensures the integrity of internal elections and surveys by facilitating secure voting systems for military personnel.
12. *Drone:* The main reason behind the increasing use of drones in the military may be economics. Drones can be used to suppress missile and air attacks. They are exceedingly cheap to produce when compared to most other weapons. Cheap

drones can easily destroy many expensive, high-tech weapons on the battlefield. With more drones being produced specifically for warfare, we are seeing new counter-drone technologies spring up. Figure 4 shows some military drones [8].

BENEFITS

Emerging technologies are capable of serving military missions for intelligence, surveillance, and reconnaissance. In a time of escalating global tension, the technological innovations provide an essential lever for both defense and deterrence. Advances in missile and weapons technologies increase lethality, making battlefield operations more effective. The introduction of emerging technologies on future battlefields will transform every aspect of combat and raise a host of challenges for advocates of responsible arms control. The US Department of Defense (DOD) addresses means of rapidly identifying, adopting, prototyping, and fielding dual-use commercial technology. It is committed to strengthening its technical advantage in a strategic environment that is increasingly being shaped by high-tech competition. Other benefits of emerging military technologies include:

1. *Warfare capabilities:* Imagine the Army having unmanned air and ground distribution platforms, the capability to manufacture replacement parts on the battlefield, and the ability to produce water from air. It imperative that the US not only seize the opportunity that artificial intelligence presents for warfighters, but to lead in its responsible development. The US has also introduced a political declaration on the responsible military use of artificial intelligence. Directed energy weapons have become much smaller and lighter.
2. *Increased spending:* The military's emphasis on artificial intelligence and robotics is growing. Investments in advanced technologies such as AI, in addition to the department's ability to leverage capabilities of US allies, is critical for deterring and preventing conflict in the future.
3. *Advanced defense:* The innovative technologies aim to provide better protection while reducing the weight burden on soldiers, thus improving mobility and comfort during extended operations.
4. *Increased efficiency:* Automation and AI can streamline logistics, maintenance, and operational planning, leading to more efficient use of resources.
5. *Training:* Virtual reality and simulation technologies provide realistic training environments, improving readiness without the costs of live exercises.

6. *Situational awareness*: Technologies such as drones, satellites, and reconnaissance systems provide commanders with comprehensive situational awareness, helping in decision-making.

CHALLENGES

The challenges of emerging technologies include rapid pace of change, security concerns, privacy violations, ethical dilemmas, regulatory uncertainty, talent acquisition, integration complexities, potential job displacement, lack of understanding about their full impact, and the need to balance innovation with stability. There is a lack of agreement in the Congress on the priorities among emerging military technologies. This has led some analysts to suggest that DOD should adopt a technology strategy to set spending priorities that can be sustained over time. The commercial companies that are often at the forefront of innovation in emerging technologies are reluctant to partner with DOD due to the complexity and secrecy of the defense acquisition process. Other challenges of emerging military technologies include:

1. *Cost-effectiveness*: Some analysts have raised concerns about the potential operational risks posed by lethal autonomous weapons and directed energy weapons. What mission(s) will these weapons be used for? Are the weapons the most cost-effective means of executing these potential missions? In what circumstances and for what purposes should the US military's use of the weapons be permissible? For example, an autonomous weapon could continue engaging inappropriate targets and this could result in mass civilian casualties.
2. *Bias*: AI can often have unintended effects like racial bias due to algorithms developed with a noncomprehensive data set. Researchers have repeatedly discovered instances of racial bias in AI facial recognition programs due to the lack of diversity in the images on which the systems were trained, while some natural language processing programs have developed gender bias. Such biases could hold significant implications for AI applications in a military context.
3. *Ethics*: Is the US military appropriately balancing the potential warfighting utility of biotechnologies with ethical considerations? What, if any, national and international frameworks are needed to consider the ethical, moral, and legal implications of military applications of biotechnologies such as synthetic biology, genome editing, and human performance modification? For example, the use of fully autonomous weapons in combat automatically

raises questions about the military's ability to comply with the laws of war and international humanitarian law, which require belligerents to distinguish between enemy combatants and civilian bystanders. Even more worrisome, some of the weapons now in development, such as unmanned anti-submarine wolfpacks, could theoretically endanger the current equilibrium in nuclear relations among the major powers.

4. *Salary Disparity*: Some reports indicate that DOD and the defense industry have difficulty recruiting and retaining personnel with expertise in emerging technologies because research funding and salaries significantly lag behind those of commercial companies. Some personnel work in the air, some on the ground or water, and others in space.
5. *Secrecy*: The US military uses communication jammers as part of electronic warfare, but many of the programs remain shrouded in secrecy. Official details are sparse.
6. *Competition*: Motivated by increasingly stiffer competition, the US is investing heavily in military weaponry that pushes the boundaries of technology. The US has remained a leader in those endeavors, with China and Russia closely following behind. If the major powers are prepared to discuss binding restrictions on the military use of destabilizing technologies, certain priorities take precedence. US is increasingly focused on developing emerging military technologies to enhance its national security and keep pace with its competitors. Although China has not been involved in real, hardcore combat for a few decades, the regular showcasing of its military might have created this aura of China being the undisputed military leader in key technological domains.
7. *Threat*: The deployment of fully autonomous weapons systems poses numerous challenges to international security and arms control, beginning with a potentially insuperable threat to the laws of war and international humanitarian law. Autonomous weapons systems could pose a potential threat to nuclear stability by investing their owners with a capacity to detect, track, and destroy enemy submarines and mobile missile launchers. Even the mere existence of such weapons could jeopardize stability. Today's stability rests on the belief that each major power possesses at least some devastating second-strike.

Addressing these challenges will not be easy, but both current and future generations must contrive novel solutions to new perils.

CONCLUSION

DOD's ability to accelerate innovation and adoption of key technologies is a critical piece of the United States' strategy to build an enduring military advantage. The technology innovation strategies of the cold war era focused on R&D of large-scale hardware and weapons systems. As today's threat environment shifts, the United States needs a more strategic approach to successfully harness the technologies of the future.

The emerging technologies discussed in this paper have the potential to reshape the defense landscape and governments will need to stay abreast of the local developments if they are to maintain a strategic and operational advantage. As these technologies are integrated into foreign and domestic military forces and deployed, they could hold significant implications for the future of international security. More information on emerging military technologies is available from the books in [9-14] and the following related magazines:

- *Military Review*
- *Technology*

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Figure 1 An autonomous weapons system [5].



Figure 2 Cyber attacks are borderless [6].



Figure 3 3D printing is used by the military [7].



China has a growing cost advantage over the US in fielding drone swarms

Figure 4 Some military drones [8].

Figures p. 70 (additive manu), 96** (China military), 145(military personnel), 117 (AI), 152(tanks of tomorrow), more books from Google Books