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Defense Primer: Emerging Technologies

Both the *2018 National Defense Strategy* and senior U.S. defense and intelligence officials have identified a number of emerging technologies that could have a disruptive impact on U.S. national security in the years to come. These technologies include

- artificial intelligence,
- lethal autonomous weapons,
- hypersonic weapons,
- directed energy weapons,
- biotechnology, and
- quantum technology.

As these technologies continue to mature, they could hold significant implications for congressional oversight, U.S. defense authorizations and appropriations, military concepts of operations, and the future of war.

Artificial Intelligence

Although there is no official U.S. government definition of artificial intelligence (AI), AI generally refers to a computer system capable of executing tasks requiring human-level cognition. AI is currently being incorporated into a number of military applications, including intelligence, surveillance, and reconnaissance; logistics; cyber operations; command and control; and semi-autonomous and autonomous vehicles. As it develops, AI could enable new concepts of operations, such as swarming (i.e., cooperative behavior in which uninhabited vehicles autonomously coordinate to achieve a task), that could present both challenges and opportunities for the U.S. military.

Recent news reports and analyses have highlighted the role of AI in enabling increasingly realistic photo, audio, and video digital forgeries, popularly known as “deep fakes.” Adversaries could potentially deploy this AI capability as part of their information operations in a “gray zone” conflict. Deep fake technology could be used against the United States and its allies to generate false news reports, influence public discourse, erode public trust, and attempt to blackmail diplomats. Some have suggested that AI could be used to create full digital “patterns-of-life,” in which an individual’s digital footprint is mapped against other personal information, such as spending habits and job history, to create comprehensive behavioral profiles of servicemembers, suspected intelligence officers, government officials, and private citizens. Similar to deep fakes, this information could, in turn, be used for targeted influence operations or blackmail.

In June 2018, the Pentagon established the Joint Artificial Intelligence Center (JAIC, pronounced “jake”) to coordinate defense-wide AI efforts. Effective February 1, 2022, the position of Chief Digital and AI Officer (CDAO) is to be established, reporting directly to the Deputy

Secretary of Defense. The CDAO is to “serve as the Department’s senior official responsible for strengthening and integrating data, artificial intelligence, and digital solutions in the department,” with the Office of the CDAO serving as “the successor organization to the JAIC.” In addition, the FY2019 National Defense Authorization Act (P.L. 115-232, §1051) established a National Security Commission on Artificial Intelligence to assess U.S. competitiveness in AI and offer recommendations to Congress. The commission concluded in October 2021.

Lethal Autonomous Weapons

Lethal Autonomous Weapon Systems (LAWS) are a class of weapon systems capable of independently identifying a target and employing an onboard weapon system to engage and destroy the target without manual human control. LAWS require computer algorithms and sensor suites to classify an object as hostile, make an engagement decision, and guide a weapon to the target. This capability would enable the system to operate in communications-degraded or -denied environments where traditional systems may not be able to operate.

LAWS are not yet in widespread development, and some senior military and defense leaders have expressed concerns about the ethics of ever fielding such systems. For example, in 2017 testimony before the Senate Armed Services Committee, then-Vice Chairman of the Joint Chiefs of Staff General Paul Selva stated, “I do not think it is reasonable for us to put robots in charge of whether or not we take a human life.” Currently, there are no domestic or international legal prohibitions on the development of LAWS; however, an international group of government experts has begun to discuss the issue. Approximately 30 countries have called for a preemptive ban on the systems due to ethical considerations, while others have called for formal regulation or guidelines for development and use. DOD Directive 3000.09 establishes department guidelines for the development and fielding of LAWS to ensure that they comply with “the law of war, applicable treaties, weapon system safety rules, and applicable rules of engagement.”

Hypersonic Weapons

Hypersonic weapons—which fly at speeds of at least Mach 5—are in development in a number of countries, including the United States. There are two categories of hypersonic weapons:

- **Hypersonic glide vehicles (HGV)** are launched from a rocket before gliding to a target. (When HGVs are mated with their rocket booster, the resulting weapon system is often referred to as a hypersonic boost-glide weapon.)

- **Hypersonic cruise missiles (HCM)** are powered by high-speed engines throughout the duration of their flight.

In contrast to ballistic missiles, hypersonic weapons do not follow a ballistic trajectory and can maneuver en route to their destination, making defense against them difficult. Currently, no such defense against hypersonic weapons exists, and experts disagree on the affordability and technological feasibility of hypersonic missile defense options. These options could include interceptor missiles, hypervelocity projectiles, laser guns, and electronic attack systems.

According to open-source reporting, Russia fielded its first HGV—the Avanguard—in December 2019. China has conducted successful hypersonic weapons tests and has also reportedly fielded an operational HGV. The United States is unlikely to field an operational HGV system before 2023. Although HCM technology is less mature than HGV technology, reports suggest that it could be fielded by Russia in 2023 and by China in 2025. Other countries—including France, Australia, India, Germany, and Japan—also have research programs in hypersonic weapons.

Directed Energy Weapons

DOD defines directed energy (DE) weapons as those using concentrated electromagnetic energy, rather than kinetic energy, to “incapacitate, damage, disable, or destroy enemy equipment, facilities, and/or personnel.” DE weapons—often colloquially referred to as “lasers”—could be used by ground forces in counter rocket, artillery, and mortar (C-RAM) or short-range air defense (SHORAD) missions. They could offer low costs per shot and nearly limitless magazines that, in contrast to existing conventional systems, could enable an efficient and effective means of defending against missile salvos and swarms of uninhabited vehicles. Theoretically, DE weapons could also provide options for boost-phase missile intercept, given their speed-of-light travel time; however, as in the case of hypersonic missile defense, experts disagree on the affordability and technological feasibility of this application.

High-powered microwave (HPM) weapons, a subset of DE weapons, could be used as a nonkinetic means of disabling electronics, communications systems, and improvised explosive devices in the event of a conflict. In addition, the U.S. military has explored using HPM in a nonlethal “heat ray” system for crowd control; however, the system was recalled—likely due to ethical and operational considerations.

Biotechnology

Biotechnology leverages life sciences for technological applications. A number of developments in biotechnology hold potential implications for national security. As a 2018 Government Accountability Office (GAO) report notes, the Departments of Defense, State (State), and Homeland Security (DHS), and the Office of the Director of National Intelligence (ODNI), all assess that biotechnologies, such as the low-cost gene-editing tool CRISPR-Cas9, have the potential to “alter genes or create DNA to modify plants, animals, and humans. Such biotechnologies could be used

to enhance [or degrade] the performance of military personnel. The proliferation of synthetic biology—used to create genetic code that does not exist in nature—may increase the number of actors that can create chemical and biological weapons” and could additionally enable the creation of adaptive camouflage, cloaking devices, or lighter, stronger, and—potentially—self-healing body and vehicle armor. U.S. adversaries may be less restrained in both researching and applying biotechnology, particularly as it relates to human performance modification and biological weapons.

Quantum Technology

Quantum technology, which employs the principles of quantum physics, has not yet reached maturity; however, it could hold significant implications for the future of encryption and stealth technologies. GAO reports that DOD, State, DHS, and the ODNI have assessed that “quantum communications could enable adversaries to develop secure communications that U.S. personnel would not be able to intercept or decrypt. Quantum computing may allow adversaries to decrypt [unclassified, classified, or sensitive] information, which could enable them to target U.S. personnel and military operations.”

Quantum technology could have other military applications, such as quantum sensing, which could theoretically enable significant improvements in submarine detection, rendering the oceans “transparent.” This could, in turn, hold implications for the survivability of the U.S. sea-based nuclear deterrent. Quantum sensing could also provide alternative positioning, navigation, and timing options that could in theory allow militaries to continue to operate at full performance in GPS-degraded or GPS-denied environments. Military application of quantum technologies could be constrained, however, by the fragility of quantum states, which can be disrupted by minute movements, changes in temperature, or other environmental factors.

CRS Products

CRS Report R46458, *Emerging Military Technologies: Background and Issues for Congress*, by Kelley M. Saylor.

CRS Report R45178, *Artificial Intelligence and National Security*, by Kelley M. Saylor.

CRS Report R44466, *Lethal Autonomous Weapon Systems: Issues for Congress*, by Nathan J. Lucas.

CRS Report R45811, *Hypersonic Weapons: Background and Issues for Congress*, by Kelley M. Saylor.

CRS Report R46925, *Department of Defense Directed Energy Weapons: Background and Issues for Congress*, coordinated by Kelley M. Saylor.

CRS Report R44824, *Advanced Gene Editing: CRISPR-Cas9*, by Marcy E. Gallo et al.

CRS In Focus IFI1836, *Defense Primer: Quantum Technology*, by Kelley M. Saylor.

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