Defense Primer: Emerging Technologies

Both U.S. national strategy documents and Congress's own bipartisan *Future of Defense Task Force Report* 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 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.

To coordinate defense-wide AI efforts, the Pentagon established the Joint Artificial Intelligence Center (JAIC, pronounced "jake") in June 2018 under the Department of Defense's (DOD's) Chief Information Officer. In addition, the FY2019 National Defense Authorization Act (P.L. 115-232, §1051) established a National Security Commission on

Artificial Intelligence (NSCAI) to assess U.S. competitiveness in AI and offer recommendations to Congress. NSCAI released its final report in March 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 may use computer algorithms and sensor suites to classify an object as hostile, make an engagement decision, and guide a weapon to the target. This capability could 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 or use of LAWS; however, international discussions—held primarily under the auspices of the United Nations Convention on Certain Conventional Weapons—are ongoing. Approximately 30 countries have called for a preemptive ban on the systems due to ethical considerations, while others have called for political declarations on or formal regulation of their development and use. DOD Directive 3000.09 establishes U.S. 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 (five times the speed of sound)—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 Avangard—in December 2019. Similarly, some experts believe that China's DF-ZF HGV became operational as early as 2020. The United States is unlikely to field an operational HGV system before 2023. Although HCM technology is less mature than HGV technology, some reports suggest that Russia could field an HCM as early as 2023. 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 report notes, the Departments of Defense, State, and Homeland Security, and the Office of the Director of National Intelligence, 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 translates the principles of quantum physics into technological applications. The Defense Science Board (DSB), an independent Department of Defense (DOD) board of scientific advisors, has concluded that three applications of quantum technology hold the most promise for DOD: quantum sensing, quantum computers, and quantum communications.

Of these, the DSB states, quantum sensing is the most mature and is currently "poised for mission use." Quantum sensing could provide alternative positioning, navigation, and timing options that could in theory allow militaries to continue to operate at full performance in GPS-denied environments. Quantum sensors could also be used in an intelligence, surveillance, and reconnaissance role. While quantum computers are in a comparatively early stage of development, they could enable advances in machine learning, a subfield of AI. Quantum computers could also potentially decrypt classified or controlled unclassified information stored on encrypted media, allowing adversaries to gain access to sensitive information about U.S. military or intelligence operations. Finally, quantum communications, which are in a nascent stage of development, could theoretically enable the secure networking of quantum military sensors, computers, and other systems. Military applications 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.

Potential Issues for Congress

- What is the appropriate balance of funding across these and other emerging technologies, given the potential military utility and technological maturity of each?

- Some analysts have argued that DOD should develop a technology strategy to establish long-term priorities across these and other emerging technologies. What impact would such a strategy have on Congress's ability to conduct oversight or evaluate budget requests?

- Some reports indicate that both DOD and defense industry have difficulty recruiting and retaining personnel with expertise in emerging technologies. In addition, analysts have noted that the development of many emerging technologies requires experts from a number of disparate fields (e.g., development of quantum technology could require experts in quantum information science, machine learning, materials science, and other fields). What measures, if any, should the United States take to ensure that the emerging technology workforce is sufficient to support U.S. competitiveness and military superiority?

Kelley M. Sayler, Analyst in Advanced Technology and Global Security

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