Congressional Research Service
Informing the legislative debate since 1914

IN FOCUS

November 23, 2021

Defense Primer: Directed-Energy Weapons

Both the 2018 *National Defense Strategy* and the House Armed Services Committee's bipartisan *Future of Defense Task Force Report* have identified directed energy as a technology that could have a significant impact on U.S. national security in the years to come. As the Department of Defense (DOD) continues to invest in directed-energy (DE) weapons, Congress may consider implications for defense authorizations, appropriations, and oversight.

Overview

DOD defines 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 include high-energy lasers (HEL) and high-powered microwave (HPM) weapons; other DE weapons, such as particle beam weapons, are outside the scope of this In Focus.

HELs might be used by ground forces in short-range air defense (SHORAD), counter-unmanned aircraft systems (C-UAS), or counter-rocket, artillery, and mortar (C-RAM) missions. The weapons might be used to "dazzle" (i.e., temporarily disable) or damage satellites and sensors. This could in turn interfere with intelligence-gathering operations; military communications; and positioning, navigation, and timing systems used for weapons targeting. In addition, HELs could theoretically provide options for boost-phase missile intercept, given their speed-of-light travel time; however, experts disagree on the affordability, technological feasibility, and utility of this application.

In general, HELs might offer lower costs per shot and—assuming access to a sufficient power supply—deeper magazines compared with traditional munitions. (Although a number of different types of HELs exist, many of the United States' current programs are solid state lasers, which are fueled by electrical power. As a result, the cost per shot is equivalent to the cost of the electrical power required to fire the shot.) This could in turn produce a favorable cost-exchange ratio for the defender, whose marginal costs would be significantly lower than those of the aggressor.

Similarly, HPM weapons could provide a nonkinetic means of disabling adversary electronics and communications systems. These weapons could potentially generate effects over wider areas than HELs, which emit a narrower beam of energy. As a result, some analysts have noted that HPM weapons might provide more effective area defense against missile salvos and swarms of drones.

In addition, some reports posit that an HPM weapon might be responsible for Havana Syndrome—the term used by some to describe a collection of symptoms experienced by U.S. Department of State personnel stationed abroad. While a National Academies of Sciences (NAS) consensus study report concluded that an HPM weapon provided the "most plausible" explanation of these symptoms from those studied, the NAS committee noted that it "cannot rule out other possible mechanisms." The U.S. government has neither identified the source of the symptoms nor attributed them to the actions of any particular government or organization.

Directed-Energy Weapons Programs

A number of countries are investing in directed-energy weapons programs. This In Focus discusses a selection of unclassified DE weapons programs in three leading military powers: the United States, China, and Russia.

United States

The DOD has a number of DE development programs underway, requesting at least $578 million in FY2022 for unclassified DE research, development, test, and evaluation (RDT&E) and at least $331 million for unclassified DE weapons procurement. For additional information about specific U.S. DE weapons programs, see CRS Report R44175, *Navy Lasers, Railgun, and Gun-Launched Guided Projectile: Background and Issues for Congress*, by Ronald O'Rourke, and CRS Report R45098, *U.S. Army Weapons-Related Directed Energy (DE) Programs: Background and Potential Issues for Congress*, by Andrew Feickert.

Many of these programs are intended to support the Office of the Under Secretary of Defense for Research and Engineering's (OUSD[R&E]) Directed Energy Roadmap. According to a presentation in 2020 by DOD Principal Director for Directed Energy Dr. Jim Trebes, who leads the department's DE efforts, the roadmap articulates DOD's objective of "[achieving] dominance in DE military applications in every mission and domain where they give advantage." The roadmap additionally outlines DOD's plan to increase power levels of DE weapons from around 150 kilowatts (kW—a unit of power), as is currently feasible, to around 300 kW by FY2022, 500 kW by FY2024, and 1 megawatt (MW) by FY2030. For reference, although there is no consensus regarding the precise power level that would be needed to neutralize different target sets, some analysts believe that lasers of around 100 kW could engage unmanned aircraft systems, small boats, rockets, artillery, and mortars, whereas lasers of around 300 kW could additionally engage cruise missiles flying in certain profiles (i.e., flying across—rather than at—the laser). Lasers of 1 MW could potentially neutralize ballistic missiles and hypersonic weapons.

In addition to the DE roadmap, OUSD(R&E) manages the High Energy Laser Scaling Initiative (HELSI), which

Principal Director Trebes notes is "to demonstrate laser output power scaling while maintaining or improving beam quality and efficiency." HELSI is intended to strengthen the defense industrial base for potential future directed energy weapons by providing near-term prototyping opportunities for industry partners. Dr. Trebes additionally notes that OUSD(R&E) has completed a DOD-wide Laser Lethality Analysis Process Review to identify future needs for the Department and best practices for DE development and use and plans to establish a Directed Energy Lethality Database that is to serve as a searchable repository for DOD's DE analyses.

China

According to the US-China Economic and Security Review Commission, China has been developing DE weapons since at least the 1980s and has made steady progress in developing HPM and increasingly powerful HELs. China has reportedly developed a 30-kilowatt road-mobile HEL, LW-30, designed to engage unmanned aircraft systems and precision-guided weapons. Reports indicate that China is also developing an airborne HEL pod.

According to the Defense Intelligence Agency, China is additionally pursuing DE weapons

> to disrupt, degrade, or damage satellites and their sensors and possibly already has a limited capability to employ laser systems against satellite sensors. China [has likely fielded] a ground-based laser weapon that can counter low-orbit space-based sensors ... and by the mid-to-late 2020s, it may field higher power systems that extend the threat to the structures of non-optical satellites.

Russia

Russia has been conducting DE weapons research since the 1960s, with a particular emphasis on HELs. Russia has reportedly deployed the Peresvet ground-based HEL with several mobile intercontinental ballistic missile units. Although little is publicly known about Peresvet, including its power level, some analysts assert it is to dazzle satellites and provide point defense against unmanned aircraft systems. Russia's deputy defense minister Alexei Krivoruchko has stated that efforts are underway to increase Peresvet's power level and to deploy it on military aircraft. Reports suggest that Russia may also be developing HPMs as well as additional HELs capable of performing anti-satellite missions.

Potential Issues and Questions for Congress

Technological Maturity

Directed-energy weapons programs continue to face questions about their technological maturity, including the ability to improve beam quality and control to militarily useful levels and the ability to meet size, weight, and power (SWaP) and cooling requirements for integration into current platforms. Some DE systems are small enough to fit on military vehicles, but many require larger and/or fixed platforms that could potentially limit deployment options and operational utility. In what ways, if any, are DOD technology maturation efforts reducing the SWaP and cooling requirements of DE systems?

Weapons Characteristics

Although HELs may offer a lower cost per shot than traditional weapons such as missiles, they are also subject to a number of limitations. For example, atmospheric conditions (e.g., rain, fog, obscurants) and SWaP and cooling requirements can limit the range and beam quality of HELs, in turn reducing their effectiveness. Traditional weapons, in contrast, are not affected by these factors. How, if at all, might HEL limitations be mitigated by technological developments, concepts of operation, or other methods? What impact might a failure to mitigate these limitations have on future military operations?

Mission Utility

Given the strengths and weaknesses of DE weapons, DOD is continuing to examine their role within the military. DOD is additionally conducting multiple utility studies to analyze potential concepts of operation for DE weapons and to assess the scenarios in which they might be militarily useful. How might Congress draw upon the conclusions of these analyses as it conducts oversight of DE weapons programs? What is the appropriate balance between DE weapons and traditional munitions within the military's portfolio of capabilities?

Defense Industrial Base

Some analysts have expressed concerns that, in the past, DOD did not provide stable funding for DE weapons programs or sufficient opportunities for the DE workforce. According to OUSD(R&E), HELSI is intended to address these concerns by providing industry with assured prototyping opportunities. In what ways, if any, has HELSI strengthened the defense industrial base for DE weapons? What, if any, challenges does the base continue to face and how might they be mitigated?

Intelligence Requirements

Some analysts have questioned whether DOD has sufficient knowledge of adversary DE weapons systems and materials to develop its weapons requirements. DOD is currently attempting to further define its DE collection requirements for the intelligence community (IC) through the Directed Energy Lethality Intelligence initiative. To what extent, if at all, is this initiative improving connectivity between DOD's DE community and the IC? What collection requirements, if any, remain?

Coordination within DOD

Pursuant to Section 219 of the FY2017 National Defense Authorization Act (P.L. 114-328), OUSD(R&E)'s Principal Director for directed energy is tasked with coordinating DE efforts across DOD and with developing DOD's Directed Energy Roadmap, which is to guide development efforts. To what extent are the military departments and defense agencies adhering to this roadmap? What, if any, additional authorities or structural changes would be required to ensure proper coordination throughout DOD?

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

John R. Hoehn, Analyst in Military Capabilities and Programs

Disclaimer