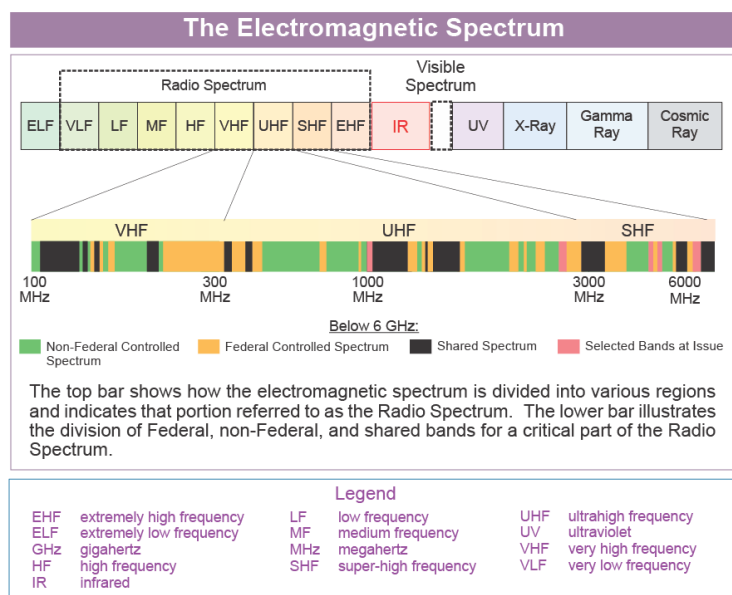


What Are DE Weapons?

According to DOD

DE is an umbrella term covering technologies that produce concentrated electromagnetic (EM) energy and atomic or subatomic particles. Directed-energy warfare (DEW) is military action involving the use of DE weapons, devices, and countermeasures to incapacitate, cause direct damage or destruction of adversary equipment, facilities, and/or personnel, or to determine, exploit, reduce, or prevent hostile use of the electromagnetic spectrum (EMS) (see Figure 1) through damage, destruction, and disruption. It also includes actions taken to protect friendly equipment, facilities, and personnel and retain friendly use of the EMS. With the maturation of DE technology, weaponized DE systems are becoming more prolific, powerful, and a significant subset of the electronic warfare (EW) mission area. DE examples include active denial technology, lasers, radio frequency (RF) weapons, and DE anti-satellite and high-powered microwave (HPM) weapon systems.²



This report examines the two most prevalent types of DE weapons: High Energy Lasers (HELs) and High Powered Microwaves (HPMs).

National Security Implications of DE Weapons³

³Unless otherwise noted, information in this section is taken from "Directed-Energy Weapons: Technologies, Applications and Implications," The Lexington Institute, Washington D.C., June 6, 2003, pp. 33-35.

DE weapons have the potential to change the very nature of warfare and could have implications for U.S. national security. Some of these potential implications are as follows:

□ DE could be used as both a sensor and a weapon, thereby shortening the sensor-to-shooter timeline to seconds. This means that U.S. weapon systems could conduct multiple engagements against a target before an adversary could respond.

□ Airborne HELs could change the nature of air combat. Aircraft with HELs could engage ballistic missiles, surface-to-air missiles (SAMs), and other airborne platforms. HELs could also be employed on stealthy unmanned combat aerial vehicles (UCAVs), enabling precision strikes against a wide variety of highly defended enemy targets. HPMs could also be used to defend U.S. aircraft against SAMs.

□ DE could also significantly improve U.S. suppression of enemy air defense (SEAD) operations, permitting, under certain circumstances, the United States to achieve air dominance over an adversary in a few days or a couple of weeks. DE weapons could rapidly locate and attack mobile SAM systems. HPM weapons could significantly improve antiradiation attack capabilities and defeat efforts by enemy air defense systems to evade detection and attack by turning off their systems.

□ DE weapons could prove an important advancement in missile defense. DE weapons could be highly effective as part of a boost-phase defense and could, if successfully developed, serve as a cost-effective counter to enemy ballistic missiles as well as associated countermeasures such as decoys and maneuverable warheads.

□ DE weapons could have the potential to preempt enemy use of weapons of mass destruction (WMD). HPM weapons, in particular, could be used to attack WMD facilities that are buried, hardened, or co-located with civilian populations or infrastructure.

□ DE weapons, particularly HPM weapons, could enhance the ability of the United States to conduct precise, effects-based operations. DE weapons could address one of the most problematic asymmetric strategies employed by adversaries: use of civilians as shields. Although HELs offer a precision strike capability to help reduce civilian casualties, HPMs could attack virtually any electronic system without doing direct harm to nearby civilians.

□ DE weapons could facilitate new strategic operations such as disrupting power generation and distribution. DE weapons could be used in selected strategic strikes against industrial systems and military infrastructure dependent on electric power and electronic systems. Effects could range from short-term disruption of service to subsystem destruction.

□ DE weapons could also provide a means by which the U.S. military could achieve limited space control. Defensively, DE weapons could provide protection of U.S. and allied space-based assets. Employed offensively, DE weapons could temporarily deny the use of space assets by adversaries and damage or destroy enemy satellites.

Kommentar [i1]: Active Denial System²⁹
The Active Denial System (ADS) was developed by Raytheon for the U.S. Air Force Research Laboratory and DOD's Joint Non-Lethal Weapons Directorate, with work starting in 2002. The ADS is a nonlethal counterpersonnel weapon that projects a focused millimeter wave energy beam that induces a painful heating sensation on an adversary's skin with the intent of repelling individuals without injury

Kommentar [i2]: U.S. Army Weapons-Related Directed Energy (DE) Programs
Congressional Research Service 3

Kommentar [i3]: Precision attack on specific personal or peoples or targeted individuals or targeted sites

High Energy Lasers (HELs)

From the Center for Strategic and Budgetary Assessments (CSBA) 2012, “Changing the Game: The Promise of Directed-Energy Weapons,”

In contrast to light bulbs that emit “white light” (photons with a multitude of different wavelengths and phases in all directions), **lasers produce narrow beams of monochromatic (single-wavelength) light in coherent beams (all photons traveling in the same direction with the same phase).** **These narrow beams can focus energy precisely on a designated point.** There are three primary types of HELs: **chemical lasers**; **solid-state lasers**; and **free electron lasers**. Beyond differences in the lasing media, each type has fundamental attributes that affect their ability to mature into operational weapon systems. In addition to the actual lasers, target tracking, laser pointing, thermal management, and beam control systems are required to place as much laser energy as possible on a target over operationally relevant distances.⁵⁹

⁴⁰ Keller.

⁴¹ Information in this section is taken from Richard D. Fisher Jr., “China’s Progress with Directed Energy Weapons,” Testimony before the U.S.-China Economic and Security Review Commission, Washington, D.C., February 23, 2017 and Elsa B. Kania, “The PLA’s Potential Breakthrough in High-Power Microwave Weapons,” *The Diplomat*, March 11, 2017.

⁴² Richard D. Fisher Jr.

⁴³ Gabriel Dominguez and Neil Gibson, “China Tests Laser-Based Counter UAS System,” *Jane’s Defence Weekly*, December 6, 2017.

In 2014, China reportedly introduced its WB-1 microwave active-denial system, similar to the U.S. Active Denial System. In 2017, China reportedly achieved “unexpected success in their *U.S. Army Weapons-Related Directed Energy (DE) Programs* Congressional Research Service 16 development of a high-power microwave (HPM) weapon.”⁴⁴ **If this alleged unspecified HPM breakthrough is successfully developed as a ship-borne antimissile system or employed as part of China’s air defense systems it is speculated that Potentially, such a weapon system would undermine the efficacy of even the most advanced U.S. missiles**, such as the Long Range Anti-Ship Missile (LRASM) currently under development. Its likely applications could also include its use as an anti-satellite (ASAT) weapon or incorporation with missiles in order to overcome enemy air defenses. Once operationalized, this new weapon could thus contribute to China’s anti-access/area-denial (A2/AD) capabilities.⁴⁵

Free Electron Lasers (FELs)

Free electron laser (FEL) systems accelerate beams of electrons to nearly the speed of light in racetrack-like accelerator rings and use powerful magnets to “wiggle” the electron beams to generate high-energy beams of laser photons. FELs are of interest to the Navy due to their potential to achieve the **high power outputs needed to interdict hardened targets such as incoming ballistic missile reentry vehicles, and their unique ability to “tune” their beams to different wavelengths to different wavelengths so they can better transmit through the dense, humid atmospheres of maritime environments.** Current developmental FELs are extremely large and inefficient.

High Powered Microwaves (HPMs)

From CSBA:

A high-power microwave weapon uses electricity to power a microwave generator that emits very short pulses—typically nanoseconds to microseconds in duration—of microwave radiation at megawatt to gigawatt output levels. Future HPM weapons could emit beams of radiation that are a few degrees wide to

attack targets in specific locations or emit radiation multi-directionally to degrade electronic components over wider areas. The effects created by HPM applications could range from temporarily disrupting electronic systems such as computers to physically burning out systems that are not shielded against the high electromagnetic fields generated by an HPM pulse. Since HPM beams cannot be as tightly focused as lasers, the energy per unit area in HPM beams decreases significantly over distance. **This could impose significant operational limitations compared to longer-range laser weapons. Since HPM weapons would affect all unshielded electronic systems within their beam spots, care must be taken when employing them to avoid collateral damage to nearby friendly systems.**⁶³

It can be argued that HPM weapons are not “true” DE weapons but they are treated as such by DOD.

Radio-frequency weapons propagate intense bursts of energy at microwave or lower frequencies that disable or destroy electronics. Such bursts can be generated by both nuclear and conventional explosives, but since these mechanisms result in omnidirectional, wideband releases of energy, they cannot properly be called “directed” energy. Radio-frequency devices producing directed energy would typically resemble radar transmitters, with steerable antennas for aiming their beams. It could be argued that radio-frequency weapons transmitting omnidirectionally but on tightly restricted frequencies are a form of directed energy.⁶⁴ Some, however, question the viability of HPM weapons.⁶⁵ Moisture in the air absorbs microwaves, and uncertainty on how electromagnetic energy flows through structures makes it difficult to predict what kind of damage an HPM weapon could do. **In addition, countermeasures to HPM weapons could be as simple as surrounding sensitive electronics with a Faraday cage.**⁶⁶

