Backgrounder

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The Use of Directed-Energy Weapons to Protect Critical Infrastructure

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America's critical infrastructure—e.g., power plants, transportation hubs, and telecommunications facilities—is becoming increasingly vulnerable to precision missile attacks. Guided missile technology and the missiles themselves have been available for years, but the emergence of global terror networks, sophisticated smuggling techniques, and the post–September 11 security environment have made the threat of precision missile attacks even more serious. While technology transfer legislation and international agreements may help to control the spread of some technologies, relying solely on these mechanisms is wholly insufficient, especially when proliferation has already occurred. Therefore, it is essential that the United States actively defend its most vital nodes of critical infrastructure.[1] To be effective against close-range missile attacks, such defenses must be cost efficient, safe, and swift.

Although the United States is not currently prepared to protect domestic targets against these threats, it does have the technology to do so with directed-energy weapons (DEWs), which include lasers, microwaves, electromagnetic pulses, and high intensity radio frequency waves. In 2000, for example, the Army used the Tactical High Energy Laser to shoot down a rocket carrying a live warhead—the first time a laser has destroyed a missile in flight.

To ensure that these promising technologies are effectively fielded in a timely manner:

- Congress should fully fund directed-energy programs;

Talking Points

- America's critical infrastructure is increasingly vulnerable to the threat of precise, airborne missile attack.
- The United States has the technology to protect against these systems with directed-energy weapons.
- Congress should fully fund directed-energy programs.
- The Department of Defense and the Department of Homeland Security should fully cooperate on their respective directed-energy efforts.
- The United States should facilitate the sharing of directed-energy technology with allies.

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- The Department of Defense (DOD) and the Department of Homeland Security (DHS) should cooperate fully on their respective directed-energy efforts;
- DHS should conduct a national needs assessment of critical infrastructure; and
- The United States should facilitate the sharing of directed-energy technology with its allies.

The Threat of Precision Strike Weapons

Although rarely considered in homeland security assessments, precision attacks using missiles—traditionally thought of as conventional weapons—pose a threat to principal U.S. infrastructure. Precision missiles can engage targets at extended ranges, from one hundred yards to thousands of miles. Whereas the military already employs certain measures to thwart such stealthy attacks abroad and defend key military installations, other more diverse and soft nodes of U.S. critical infrastructure are less well-defended and often not defended at all. With an ever-increasing potential for terrorists to procure missile technologies and weapons, precision missile strikes could represent an enduring threat from both terrorists and rogue states. There are numerous precision systems around the world that could threaten America's critical infrastructure.

- **Short-range threat.** Man-portable air defense systems (MANPADS) were originally developed to defend against military aircraft. However, terrorists have used them to target passenger aircraft. They have precision strike capabilities, are globally available, and come in a variety of configurations and capabilities.[2] Not only could MANPADS be used to down an airliner, but they could also be used to target vulnerable points at ground facilities such as power plants. At about 35 pounds and 6 feet long, MANPADS are relatively easy to conceal and transport.[3] Anti-tank guided missiles (ATGMs) have similar capabilities. An ATGM weapon, guidance system, and ammunition could fit in a car trunk, and ATGMs are readily available on the arms black markets. These systems could be used to target any number of critical infrastructure nodes, such as major financial facilities, water treatment plants, and even primary government buildings.
- **Longer-range threat.** The cruise missile threat is also growing. While relatively few nations have land-attack cruise missiles, many have anti-ship cruise missiles. Although these systems were developed to target ships at sea, they could also be modified and turned against civilian infrastructure along America's shorelines, or they could be used simply as weapons of terror by launching them indiscriminately at populated areas. The short-range ballistic missile threat is also growing. Although few nations possess intercontinental-range capabilities, many nations do have short-range ballistic missiles. These missiles could be transported globally on cargo ships and launched at the U.S. homeland.

Why Directed-Energy Weapons

Directed-energy weapons have singular characteristics that make them uniquely appropriate to addressing the short-range missile threat, and they would prove immensely valuable employed as part of critical infrastructure defense. They could protect high-risk structures, such as major government buildings, major transportation nodes, vital commercial assets, power plants, and airports. Although other options may exist that could protect critical infrastructure (e.g., surface-to-air mis-

1. As defined by Congress, critical infrastructure means "systems and assets, whether physical or virtual, so vital to the United States that the incapacity or destruction of such systems and assets would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters." *USA PATRIOT Act of 2001*, 42 U.S.C. § 5195c(e).
2. For further reference on the threat of MANPAD, see James Jay Carafano, Ph.D., and Jack Spencer, "Facts About the Shoulder-Fired Missile Threat," Heritage Foundation *Web Memo* No. 328, August 14, 2003, at *www.heritage.org/Research/HomelandDefense/wm328.cfm*.
3. Northrop Grumman, "HORNET Commercial and Military Aircraft Defense System," August 14, 2003.

sile batteries, fighter aircraft surveillance, and arms control legislation), in the long run none are as cost effective, precise, safe, or swift as a directed-energy defense system.

What Are Directed-Energy Weapons? Directed-energy weapons include a host of technologies, including lasers and microwave radiation emitters. These weapons can inflict casualties and damage equipment by depositing energy on their intended target. Compared with conventional weapons, which rely on the kinetic or chemical energy of a projectile, DEWs hit a target with subatomic particles or electromagnetic waves that travel at speeds at or near the speed of light. DEWs generate very high power beams and typically use a single optical system to both track a target and to focus the beam on the target in order to destroy it.[4]

Lasers—the most mature form of directed-energy weapon that can counter airborne threats—form intense beams of light that can be precisely aimed across many kilometers to disable a wide range of targets: from satellites to missiles and aircraft to ground vehicles.[5] Additionally, the laser beam can be redirected by mirrors to hit targets not visible from the source—all without compromising much of the beam's initial power.

In 1996, the U.S. Army and the Israeli Ministry of Defense began to develop a short-range tactical high energy laser (THEL), which has since become the most successful laser-based anti-missile program in history. It is the most advanced directed-energy technology that the American armed forces have available to protect critical infrastructure. Demonstrating the unique threat flexibility of laser weapons, THEL has intercepted dozens of threats and a growing list of different threat types, including a large number of Russian *Katyusha* rockets, five artillery shells, and, more recently, large caliber rockets. The Army is preparing to build a mobile prototype (Mobile THEL or MTHEL), which will add mobility and high operational readiness. MTHEL could protect against the kind of rocket and mortar threats that U.S. troops have been facing in Iraq and Afghanistan. HORNET (a slightly different, upgraded MTHEL configuration) could also protect an airport against a full range of MANPADs and other precision strike threats.

Protecting Critical Infrastructure. Future directed-energy weapons may offer the greatest improvements to U.S. defenses. For example, within a decade, American military developments in MTHEL could produce prototype weapons capable of providing area-wide point defenses against artillery, rockets, mortars, missiles, and low-flying unmanned aerial vehicles. Ground-based lasers are being designed not only for battlefield uses, but also to protect Israeli population centers from terrorist attacks with *Katyusha* rockets and other improvised rocket, artillery, and mortar systems.[6]

Such systems could be employed in the U.S. as well. These weapons could be deployed at airports to defend planes from attacks by shoulder-fired missiles (and by makeshift rockets and missiles) during takeoff and landing—the times when aircraft are most vulnerable. With most airports located in or near major urban centers, DEWs could help to address the near impossibility of providing adequate, credible security zones around airports. Furthermore, DEWs could defend coastal airports from

4. Loren B. Thompson, Ph.D., "The Emerging Promise (and Danger) of Directed-Energy Weapons," Lexington Institute Capitol Hill Forum on Directed Energy, July 11, 2002, at *www.lexingtoninstitute.org/defense/energyforum_thompson.htm* (July 23, 2004).
5. *Ibid.*
6. Josef Schwartz, *et al.*, "Tactical High Energy Laser," presented at the SPIE Proceedings on Laser and Beam Control Technologies, January 21, 2002, pp. 1–6. TRW developed a fixed-site THEL under an $89 million contact. In tests, the system has successfully shot down 25 rockets. It is, however, not currently capable of being deployed for operational use. The U.S. Army is developing a mobile version and has requested additional funding for the program. In February 2004, the Army's tactical laser project was formally transitioned into an acquisition program. The first prototype of the mobile laser is due to appear in 2008. See Loren B. Thompson, Ph.D., and Daniel Gouré Ph.D., "Directed Energy Weapons: Technologies, Applications, and Implications," Lexington Institute *White Paper*, February 2003, pp. 11–12 and 24–25, at *www.lexingtoninstitute. org/defense/DirectEngery.pdf* (July 23, 2004).

attacks launched from a commercial or private ship loitering offshore—a potentially ideal platform for launching precision strikes.

Unique Advantages of Directed-Energy Weapons. During the past two decades, directed-energy projects have advanced considerably in areas such as power, beam-control, and pointing and tracking techniques. This progress accounts for the U.S. government's growing interest in directed-energy technology. The unique features and advantages of DEWs may arguably revolutionize concepts of military operations, as well as greatly influence civilian protection.

- **Operating at the speed of light.** DEWs' first significant advantage is that their destructive mechanisms (electromagnetic beams) travel at the speed of light. Naturally, this almost instantaneous impact across great distances simplifies the tracking and intercepting phases of missile defense and greatly diminishes the target's ability to evade interception. DEWs effectively eliminate many problems associated with fly-out time for existing weapons because virtually no time elapses between firing a DEW and its impact on target.
- **Gravitational immunity.** Laser beams are unaffected by gravity or atmospheric drag. Simply, energy beams are essentially immune to gravity due to their lack of mass, which also frees them from the kinematic and aerodynamic constraints that limit more traditional weapons. Hence, the complex calculations required to determine ballistic trajectories and other flight characteristics of conventional munitions are irrelevant to directed-energy devices.[7]
- **Precise and adjustable targeting.** DEWs offer extremely precise targeting, which allows for surgical strikes with no collateral damage or fratricidal effects on friendly forces. This would be particularly advantageous when operating near volatile workstations, such as nuclear and chemical plants. A related feature of DEW technology is the ability to customize the weapon by adjusting the amount of energy deposited upon targets. This allows for a wide range of results: lethal or non-lethal, destructive or disruptive.[8] As Air Force Chief of Staff General Ronald Fogelman articulated, "DEWs are the opposite of weapons of mass destruction—they are the most promising precision non-lethal weapons we have."[9]
- **Affordable.** Once fully deployed, DEWs will likely be able to intercept targets at a relatively low cost when compared to conventional munitions. Although the beam-generating system may be initially expensive to build and maintain, the price of engagements is minimal because the system expends only energy. In the case of missile defense, the threats are typically extremely cheap. On the other hand, interceptor missiles can cost millions of dollars, creating a tremendous cost imbalance that favors the attacker. With laser weapons, some missiles can be replaced with a DEW costing only a few thousand dollars per shot to achieve equivalent or superior probability of kill. For example, a THEL shot is estimated to cost about $8,000.[10] In comparison, firing a PATRIOT (PAC-3) missile costs $3.8 million; an AIM-7 Sparrow missile costs approximately $125,000; and a Tomahawk cruise missile costs roughly $600,000.[11] Firing a DEW is an extremely economical way to combat MANPADS and artillery, the current threats to U.S. critical infrastructures.
- **Repetitive engagements.** DEWs have a capacity for repetitive engagements over protracted periods, constrained only by the availability of

7. Thompson and Gouré, "Directed-Energy Weapons."
8. *Ibid.*
9. *Ibid.,* p. 5.
10. Sandra Erwin. "Directed Energy Weapons Promise Low Cost per Kill," *National Defense Magazine*, September 2001, at *www.nationaldefensemagazine.org/article.cfm?Id=591* (July 23, 2004).
11. U.S. Navy, "Fact File," updated June 14, 2004, at *www.chinfo.navy.mil/navpalib/factfile/ffiletop.html#missiles* (July 23, 2004).

power and the need to vent the byproducts of beam generation (e.g., heat and chemicals). Conventional weapons, especially those firing precision-guided munitions, are typically constrained in the number of engagements by a limited supply of rounds. Even when the rounds are cheap expendables, space and weight limitations place a ceiling on how many engagements can occur without replenishment. DEWs are not entirely free of such considerations but they have the potential for much deeper magazines arising from the low-cost and high-energy potential of their power sources. Finally, a DEW provides the versatility of serving as a sensing device as well as a weapon. Lasers can be used not only to attack targets, but also to detect, image, track, and illuminate ("acquire") them. High-power microwaves operate in the same wavelengths as radars, giving them similar tracking potential in some applications.

- **Diverse.** Directed-energy weapons could be based on a variety of platforms, and they come in a wide range of power levels. For local asset defense, comparatively small systems can quickly kill very short-range targets by focusing the laser's tremendous power precisely on a target's most vulnerable point. Larger systems could generate even high power levels, roughly equivalent to two sticks of dynamite, focused in a beam about the diameter of a basketball. Such a weapon can kill a target moving at one thousand miles per hour at a distance of up to several hundred miles, within a few seconds of acquiring the target.[12]

What Should Be Done

To take full advantage of directed-energy weapons for use in securing critical U.S. infrastructure, the Bush Administration and Congress should take the following actions:

Fully fund directed-energy research and development programs. While DEW research and development programs have been extremely successful during the past two decades, additional funding could provide an even greater revolution of both offensive and defensive weapons. Despite the numerous unique advantages of DEWs, the system has a few challenges or drawbacks. For example, as with all lasers operating in the lower atmosphere, dust, fog, smoke, and other battlefield obscurants can attenuate laser beam energy.[13] Another challenge is combining all the components of a laser weapon into a functioning and reliable system—an integration-level challenge.[14] With greater funding, research and development programs could overcome these difficulties.

- **Require cooperation between the Department of Defense and the Department of Homeland Security.** To facilitate greater efficiency in DEW research and development, the Administration should establish a cooperative program between the DOD and the DHS to ensure that directed-energy information and technology are freely exchanged between the two departments. Protecting commercial aircraft, major government facilities, nuclear and chemical power plants, and transportation nodes against precision missiles is a concern for both DHS and the U.S. military. By cooperating, these departments can accomplish more at an increased speed. It is imperative that they jointly develop both the means and the technologies necessary to meet the threat of missile attacks on critical infrastructure.[15] Without such cooperation, the departments will almost certainly duplicate research and produce less (at greater cost) than they would by working together.

12. Thompson and Gouré, "Directed-Energy Weapons," pp. 19–37.
13. *Ibid.*, pp. 3–18.
14. *Ibid.*
15. James Jay Carafano, Ph.D., "Strategy and Security in the Information Age: Grading Progress in America's War on Terrorism," Heritage Foundation *Lecture* No. 824, March 17, 2004, at *www.heritage.org/Research/HomelandDefense/hl824.cfm*.

- **Conduct a national needs assessment of critical infrastructure.** To ensure maximum efficacy, the DHS should conduct a national needs assessment of critical infrastructure, identifying and categorizing the potential security threats against specific structures. In the past, vulnerability assessments tended to focus on the threat of long-range weapons, such as intercontinental ballistic missiles, or close-in assaults, such as truck bombs. Regrettably, the variety of infrastructure targets has not been detailed, leaving significant uncertainty as to these structures' level of vulnerability. Researching this area of concern is imperative in order to deploy a DEW defense system effectively.
- **Facilitate the sharing of directed-energy technology with U.S. allies.** The Administration should establish a homeland security equivalent of the Foreign Military Sales program that would allow the sharing of directed-energy technology with friends and allies for critical infrastructure defense. The United States has already had some successful bilateral technology sharing of counter-terrorism tools with individual countries, such as Israel. However, while the mechanism for developing and transferring defense technologies on a military-to-military basis is fairly mature, the United States lacks a sophisticated approach to sharing technologies and lessons learned for civilian homeland security needs.

  Countries with sophisticated technology, such as the United States and India, should enter into a serious dialogue to determine what a future homeland security technology development regime might look like. Among other things, such a dialogue would require: (1) a technology clearinghouse so that the partners know which technologies are available for transfer; (2) a method of setting standards so that technologies are understandable; (3) interoperable and transferable means for industry-to-industry dialogue; (4) predictable export-control requirements; and (5) acquisition mechanisms, such as joint development programs, licensing agreements, and something comparable to the Foreign Military Sales program.

Conclusion

Although directed-energy weapons have been on the horizon for many years, never has their potential been so essential to homeland security. The United States needs to put the resources behind this promising technology now so that it can better protect its critical infrastructure in the near future.

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