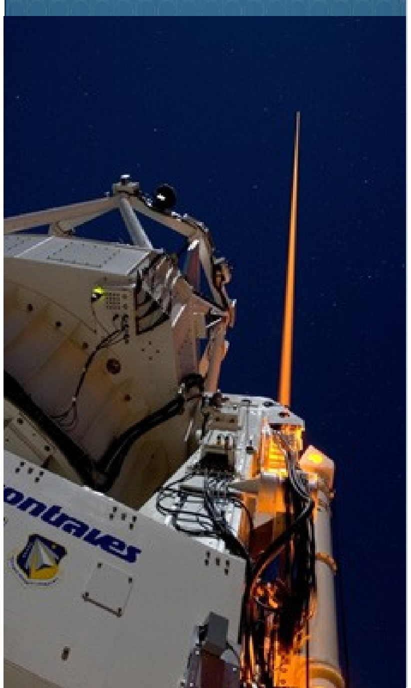
AFRL

THE AIR FORCE RESEARCH LABORATORY

Directed Energy Directorate

Speed of Light to the Fight by 2020



AFRL Directed Energy Directorate

Laser Weapon Systems

Why Laser Weapon Systems

The Department of Defense (DoD) invests research and development (R&D) dollars into directed energy solutions to fill gaps identified by warfighters. Currently, the Air Force is pursuing laser weapons systems (LWS) along with high powered electro-magnetics (HPEM) to enable operations in a possible future battlespace involving a technologically advanced adversary with the ability to prevent access to—or deny our ability to operate in—a given area. There is also increased interest in defending against Unmanned Aerial Systems (UAS) and hypersonic weapons.

Laser technology has made significant leaps in both performance and maturity thanks to many years of research. Recent developments in electric solid-state and fiber lasers, designed primarily for tactical engagement, now offer weapons-grade power in a compact system suitable for deployable platforms. For example, the Navy, by virtue of its Laser Weapons System dubbed LaWS, has fielded the DoD's first operational tactical laser on a ship, overcoming many of the policy and legal issues hindering deployment and utilization. Today, laser weapons have finally demonstrated sufficient technical maturity to allow for integration onto air platforms for potential self-defense and offensive missions in the next decade.

Overcoming Challenges

The Air Forces past airborne laser demonstrations pushed the art-of-the-possible, providing an appreciation both for the unique operational capabilities of an airborne LWS and for the formidable technical challenges that remain to be overcome. Due to the sub- and transonic air speeds of maneuvering tactical aircraft—such as fighter planes—in conjunction with tight packaging constraints, these obstacles are far greater for aerial vehicles than for ground-based systems. Naturally, these mutually interdependent challenges must be addressed concurrently before an LWS can be integrated into an aerial vehicle.

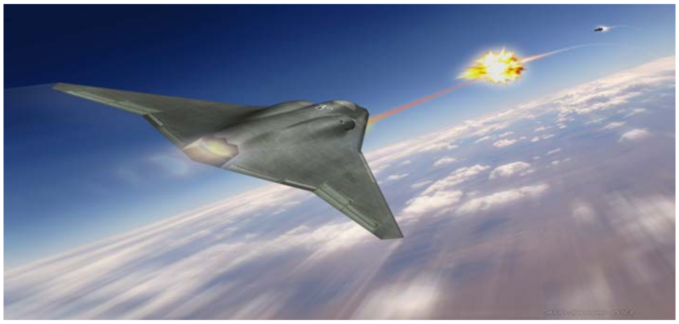
A variety of obstacles impede the utilization of an airborne laser weapon system, several of which have been identified as being most crucial to its success or failure. Most fundamentally, it is essential to maximize laser power while reducing volume and mass, maintaining a size, weight, and power (SWaP) that offers tactical effectiveness. Moreover, beam control systems must be adequately advanced so as to enable precise aiming, tracking, and pointing amidst the aero-mechanical jitter induced by vibrations during flight. Similarly, system temperature must be controlled via the dissipation of waste heat, and high-speed aerodynamic flow must be mitigated to avoid aero-optical disturbances. Should any of these elements be allowed to dominate, the laser beam can disperse, losing its precision and effectiveness at operational ranges. Finally, it is important to note that a laser system is a complex piece of technology, which must be ruggedized into a compact package capable of surviving a battlefield environment.

In the face of these multiple technical difficulties, AFRL plans to build on past demonstrations and advancements to sponsor a staged approach to address and reduce technology risks. Initially, the focus will be on the development of subsystem technologies, making certain that each component of the greater whole can meet the requirements of the operational Air Force. A flight demonstration with a low-power laser will prove that targets can be tracked at sufficient range and speed to allow for engagement with a laser beam, demonstrating effective mitigation of aerodynamic disturbances. Successful completion of this demonstration will lead to the graduated progression of ground and flight tests for laser weapon systems offering medium-power for tactical operations.

The continuing development and eventual deployment of high-power laser systems has the potential to diminish operational risk, create improved warfighting options, and enable new courses of action for military leadership. These airborne demonstrations mark the first AFRL sponsored laser weapon flight program in more than 30 years and are in direct response to the importance placed by senior Air Force leadership on rapidly maturing these systems for operational use.

Laser Source Characteristics

Laser weapons can deliver precise and scalable effects against a wide class of targets near-instantaneously and at a very low cost per shot. For example, the type of gradual effects a 30kW laser can deliver includes the denial, degradation, disruption, and destruction of a range of targets from UAS to small boats at a range of several kilometers. More powerful lasers have counter-air, counter-ground, and counter-sea applications against a host of hardened military equipment and vehicles at significant range.



Due to the complex logistical chain of chemical lasers, electrically-driven solid-state lasers have become the medium of choice for the modern LWS. These lasers have few moving mechanical parts and consume only electricity, rather than hazardous and caustic chemicals. As such, solid-state lasers are a fraction of the size of chemical lasers, and their weight per power (kg/kW) is about 30 times less, allowing for great savings in space for electric lasers. Beyond considerations of size, solid-state lasers offer a host of advantages.

Electric lasers have a nearly infinite "magazine size" as long as an appropriate power supply is available. As such, the total number of shots they can fire is limited only by the fuel available to drive the electrical power source, provided naturally via the operation of the aircraft. Generally, banks of batteries are employed for this purpose and can be sized to meet the requirements for virtually any laser power and magazine depth. For a 30 kW laser system, the batteries could weigh on the order of 300 pounds and fit within a volume of half of a cubic meter. Since they are constantly powered—"reloaded"—by recharging their electrical power supply, an LWS can engage multiple targets very quickly and is limited for the most part only by its ability to dissipate waste heat. Effective thermal management systems can drastically increase the rate of fire, either through traditional liquid cooling loops or through two-phase cooling, wherein heat is transferred to and melts a solid, the resulting liquid of which is then cooled.

Functionally, the range of an LWS is dictated by laser power, beam quality, aero-optical and aero-mechanical disturbances, and beam control design. Weather and atmospheric conditions can also serve to limit effective range.

Current Laser Programs

AFRL has two major integration and demonstration programs at the moment: the Self-Protect High Energy Laser Demonstrator (SHiELD) and the Demonstrator Laser Weapon System (DLWS). The former addresses the risk of integrating a LWS onto an aerial platform, while the latter demonstrates the effect of a fully integrated ground-based LWS against representative targets. In addition, several enabling research programs are being conducted to tackle key technical challenges at the subsystem level. In total the Air Force and DARPA are investing more than $500 million on these programs. The Army, Navy, the Defense Advanced Research Projects Agency (DARPA), and the Missile Defense Agency (MDA) are also investing in the maturation and integration of solid state laser technology on relevant platforms for their applications. Major aerospace industry partners include General Atomics, Raytheon, Boeing, Northrop Grumman, and Lockheed Martin.

The SHiELD Advanced Technology Demonstration (ATD) is a two-phased effort to showcase the ability of a podded laser system. The program will develop and integrate a more compact, medium-power LWS onto a fighter-compatible pod to demonstrate effectiveness of a LWS in a relevant flight environment for self-defense against ground-to-air and air-to-air weapons. The purpose of the SHiELD ATD is to reduce and retire the risk of an airborne LWS in a calculated and precise fashion, meeting and resolving the aforementioned technical challenges of power-scaling, beam quality, thermal management, and packaging. In its first phase, the flight demonstration is expected to prove that targets can be tracked at sufficient range and speed to subsequently engage with a laser. In the next phase, a moderate-power laser will be incorporated to assess the performance of the LWS in an operationally relevant environment. Flight tests should occur in the FY20 timeframe.

The DLWS program is an effort funded jointly by the Defense Advanced Research Projects Agency (DARPA) and the Air Force. Its purpose is to integrate DARPA's 150 kW-class electric laser (HELLADS—High Energy Liquid Laser Area Defense System) with the Army's beam control system at White Sands Missile Range, addressing the integration challenges for a ground-based LWS. This will demonstrate the lethality of a fully integrated solid-state laser weapons system against representative ground-based and surface-to-air targets of interest to Air Force Special Operations Command (AFSOC) and Air Combat Command

(ACC), respectively. Such targets will include rockets, mortars, and surface-to-air missiles. Key features of the DLWS involve using infrared or optical signals to acquire, track, and hold a precise point on a target, and allowing the laser to deliver sufficient energy to disrupt, disable, or destroy it. AFRL is currently engaged with AFSOC to discuss how existing and planned airborne and ground demonstrations of a LWS could address their requirements. The team is currently integrating the laser with the beam control system, and testing should begin shortly.

AFSOC Interest

The AFSOC commander has recently stated his interest in both defensive and offensive directed energy capabilities in the AC-130 airframe against a varied target set. Performance requirements for the full range of AFSOC missions have yet to be specified, but AFRL assesses that a defensive LWS that weighs less than 5000 lbs. is feasible. Our target weight for a podded solution on a fighter is less than 1500 lbs.

AFRL's laser programs are aiming to achieve a laser weapon system that can operate in all flight regimes against targets that are approaching at supersonic speeds, which must be intercepted at significant ranges. In the process of achieving these goals, the incremental approach described above will address AFSOC requirements. The AC-130 gunship is slower moving with larger volume and weight allowances, and their target sets will likely be at closer range. As such, the laser weapon technology needed to address the AFSOC concept should naturally develop while pursuing the farther-reaching lasers for a tactical platform, though the AFSOC AC-130 gunship laser weapon concept will still require customization to address unique target sets and concepts of employment.

Contact 377 ABW Public Affairs for more information: (505) 846-5991 DSN 246-5991

Reviewed December 2016
http://www.kirtland.af.mil/afrl_rd/index.asp
Approved for Public Release - OPS-15-1038