



LASER WEAPON SYSTEM (LAWS) ADJUNCT TO THE CLOSE-IN WEAPON SYSTEM (CIWS)

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Report Documentation Page

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The Naval Sea Systems Command (NAVSEA) established the Navy Directed Energy Weapons Program Office in January 2002 and subsequently chartered the Directed Energy and Electric Weapon Systems Program Office (PMS 405) in July 2004.^{1,2} Its mission is to change the way the Navy fights in the 21st century by transitioning directed-energy and electric weapon technology, providing the warfighter with additional tools to fight today's and tomorrow's wars. In support of this mission, the Laser Weapon System (LaWS) was developed, which potentially adds a suite of tools for offensive and defensive operations.

The LaWS program is managed by PMS 405 in cooperation with the Program Executive Office Integrated Warfare Systems (PEO IWS), the Navy's Close-In Weapon System (CIWS) manager. A multilaboratory/multicontractor organization led by the Naval Surface Warfare Center, Dahlgren Division (NSWCDD), has been executing the program since March 2007. The potential advantages of a lethal, precise, speed-of-light weapon are numerous and have been recognized for many years. However, even in light of these advantages, there are realities that need to be considered for any program to succeed to the point that an actual system is placed in the hands of the warfighters.

The LaWS system offers viable solutions for an important subset of threats while fitting into acceptable size and weight constraints. In addition, since LaWS is a fully electric laser, the operation of the system does not require the handling and storage of hazardous chemicals, such as hydrogen fluoride. As will be discussed later, due to the incorporation of high levels of commercial off-the-shelf (COTS) technology, the LaWS system also has advantages for topside design, logistic supportability, and cost. Thus, LaWS could enable the Navy to address adverse cost-exchange situations, which can occur when engaging proliferated inexpensive threats such as unmanned aerial vehicles (UAVs).

BACKGROUND

Based on mission analysis work conducted prior to the LaWS program and additional work done as part of the program, it became clear that a number of factors require careful consideration. First, a high-power laser is not likely to replace anything on a ship in the next 5 years. For a new system to be added to a ship, a high-power laser must supplement current capabilities or provide new capabilities that clearly justify its addition. Second, because a laser provides such a diverse set of capabilities, conventional air-to-air warfare (AAW) models—

such as the Fleet AAW Model for Comparison of Tactical Systems (FACTS), Antiair Warfare Simulation (AAWSIM), and Extended Air Defense Simulation (EADSIM), as well as other existing AAW analysis approaches—are not well suited for showcasing current or near-term laser-weapon capabilities. While they can (and have) been used for laser-weapon analysis, their application to a megawatt-class laser that could “instantly” destroy boats or cruise missiles (akin to missile engagements) is a more straightforward application of the existing models and techniques.

In November 1995, the Chief of Naval Operations requested that the National Research Council initiate, through its Naval Studies Board, a thorough examination of the impact of advancing technology on the form and capability of the naval forces to the year 2035. A major observation of the report is quoted below:

Numerous laboratory and field-test versions of laser weapons have been developed and demonstrated. They have worked as expected and demonstrated suitable lethality against their intended targets. The primary factors that have inhibited the transition of the technology into deployed systems are size and weight. Generally, the conceptual designs of laser weapons that are scaled for combat effectiveness are too large to be appealing to users; conversely, weapons that are sized for platform convenience generally lack convincing lethality.³

Subsequently, an August 2006 U.S. Air Force (USAF) Scientific Advisory Board Study examined the increasing threat posed by UAVs in some detail. Key conclusions included:

No single system can completely address the UAV threat. A single sensor solution is inadequate because of the size and speed challenges presented by small UAVs. A single-weapon-layer solution fails to provide for adaptability to multiple scenarios or adequate probability of kill.

Key recommendations of the USAF Advisory Scientific Board Study included:

Develop and field longer-term upgrades to counter increased UAV threats. They include...a small, multimission air/air and air/ground weapon; and directed-energy air defense weaponry.⁴



In addition to the USAF Scientific Advisory Board study, a 2007 OPNAV Deep Blue Study noted the potential advantage of nonkinetic defeat options and recommended that the Navy accelerate development of nonkinetic systems to include high-energy lasers (HELs).⁵

The laser power levels likely to be available in the near term, within reasonable size and cost, are in the neighborhood of 100 kW of radiated power. While this power level is not adequate to engage certain threats, such as cruise missiles or tactical ballistic missiles at tactically useful ranges, there is still a wide spectrum of threats that could be engaged at ranges that are comparable to many current ship-defense weapons, including minor-caliber guns and small missiles. The spectrum of threats includes:

- UAVs
- Missile Seekers
- Intelligence, Surveillance, and Reconnaissance Systems
- Rockets
- Man-Portable Air-Defense Systems (MANPADS)
- Mortar Rounds
- Floating Mines
- Artillery Rounds

LAWS ON CIWS

The Mk 15 Phalanx CIWS can often detect, track, and (sometimes) identify potential threats at ranges well outside the effective range of the 20mm gun. These functions are accomplished using the search/track radar system and the Phalanx Thermal Imager (PTI). When added to the Phalanx mount and pointed in the same direction as the gun (see Figure 1), a laser weapon could potentially add a number of useful functions and capabilities to the mount, but technical challenges must be overcome. Preliminary analyses of the mechanical characteristics of the mount suggest that the additional weight that could be added to the mount must be kept under approximately 1200–1500 lb. Additionally, it is highly desirable that the addition of the laser weapon not substantially affect the train/elevation operation of the mount in angle, peak velocity, or acceleration. Consequently, use of rapidly evolving fiber laser technology appears to be the only currently foreseeable path to adding significant laser energy directly to the mount within these constraints.

One major driver in the genesis of the LaWS system was the availability of relatively

low-cost COTS fiber-optic lasers. Because these fibers are flexible, they obviate the need for an expensive coude path system (an optical mirror/lens assembly that turns radiation 90° and may also support rotation of the beam director), thus allowing the use of low-cost mount technology, as well as the retrofitting of the system on existing mounts. The last factor is extremely important because of the scarcity of topside real estate on today's ships. These fiber-optic lasers do have limitations in terms of power, although power levels are growing with advancing technology. The reality today is that, in order to get adequate lethality from a system based on this technology, the use of a beam-combining apparatus utilizing several individual fibers is necessary. (Figure 2 depicts combining multiple fibers in the same beam director.) Furthermore, a smaller beam size is desirable since this drives power density up—increasing the performance required for the tracking and pointing elements of the system. Thus, a high-resolution fine track sensor is needed, as well as an appropriately robust line-of-sight control.

A POTENTIAL SUITE OF LAWS-RELATED CAPABILITIES

Potential added capabilities that an adjunct LaWS could contribute to the total ship combat system are briefly outlined in the following subsections.

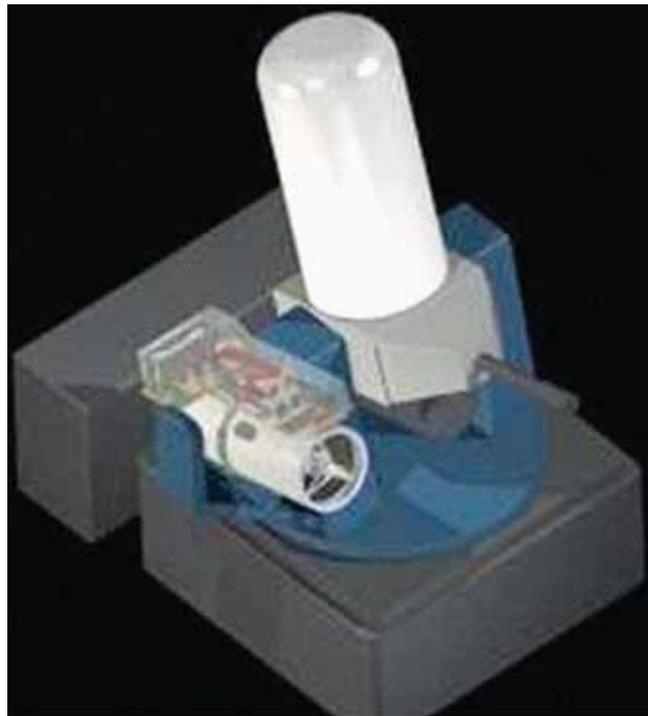


Figure 1. LaWS Mounted on CIWS

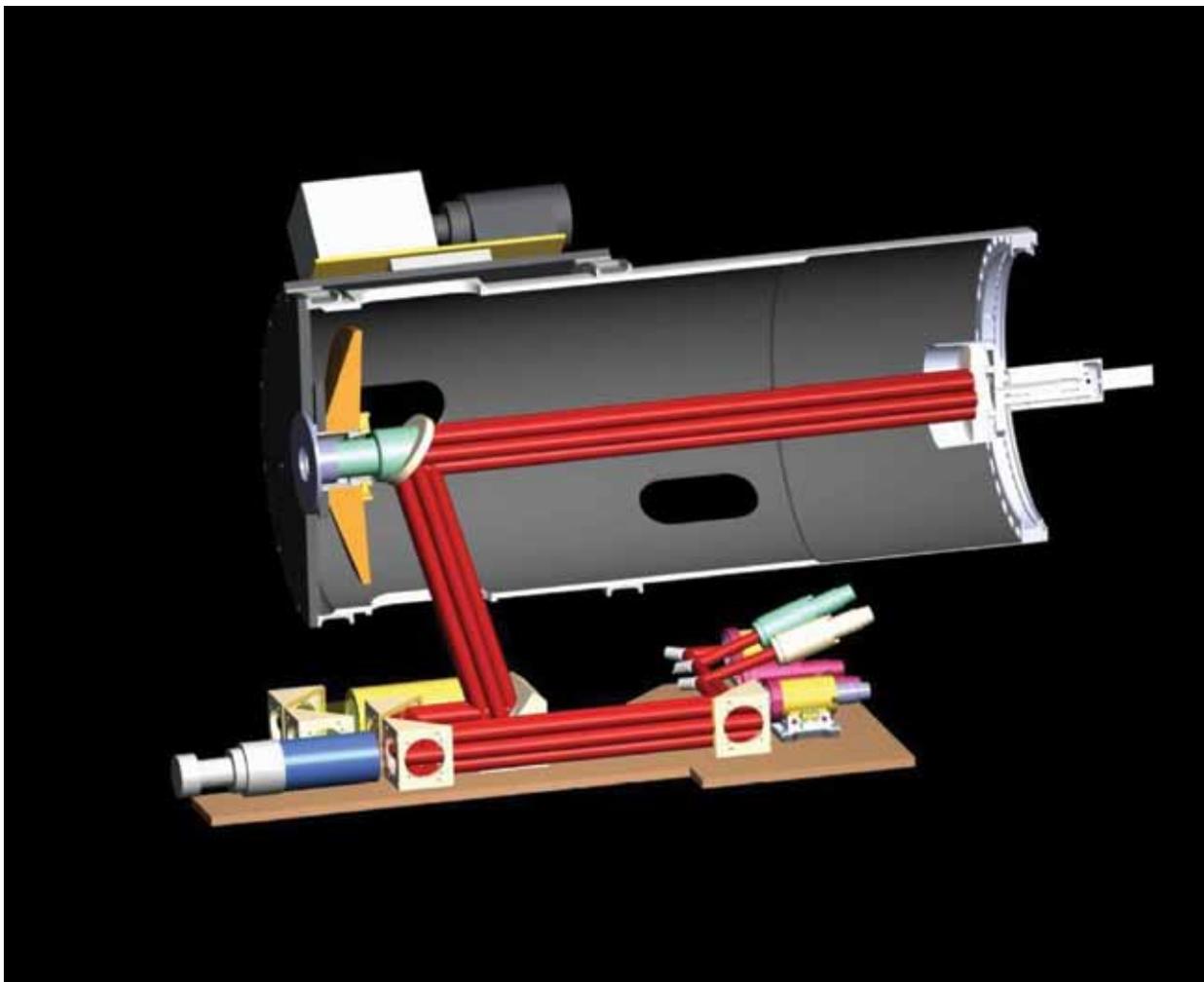


Figure 2. Cutaway View of the LaWS Beam Director

Target Identification, Tracking, and Intent Determination at Range

The optics that would be added for the laser to detect and track targets in support of a laser engagement would immediately contribute additional capabilities to the entire ship combat system even without operating the laser. A laser-gated illuminator, part of the tracking system, significantly increases the signal to the background level of tracked targets and provides good range resolution as well. The additional sensitivity and angle resolution provided by the LaWS optics would allow the identification, precision tracking, and “monitoring” (at high resolution) of potential threats or vehicles of interest at substantially greater ranges than could be achieved by the PTI alone. The Phalanx radar, or another source, would have to provide an initial, accurate cue to facilitate initial acquisition. Once acquired, the target could be examined and monitored with high resolution at range. This capability could

make a substantial contribution to identification efforts—efforts to determine intent and potentially even to documenting target behavior to resolve issues with rules-of-engagement doctrine. It is widely recognized that rules-of-engagement issues, such as threat identification and intent determination, are among the most difficult problems faced by ship commanding officers.

Unambiguous Warning at Range

If a fraction of the laser energy is routed through a frequency-doubling crystal, an intense, visible beam can be projected to significant ranges to provide a clear, unambiguous warning that a potential target is about to be engaged unless an immediate change in behavior is observed. This feature also would have utility for dazzling aircraft, surface vehicle, or submarine sensors, and would provide exceptional long-range, unambiguous warning to boats or aircraft at night.



Sensor Destruction at Range

Many electro-optical (EO) sensors are quite susceptible to damage by laser energy in the fiber-laser band as is the case with infrared (IR) missile seekers with germanium optics. The frequency-doubling feature described in the previous paragraph also would be useful to ensure that a band-pass filter at a single frequency could not be applied as an effective countermeasure. The intent here would be to destroy the seeker or imager at ranges well beyond those achievable by the Phalanx 20mm gun. Other examples include intelligence, surveillance, reconnaissance, and targeting sensors on UAVs or unmanned surface vehicles (USVs).

IR Missile Assist at Range

Many targets of interest—including UAVs, USVs, and small boats—are somewhat “marginal” from a target-signature standpoint, particularly at the maximum range of existing IR guided missiles such as the FIM-92 Stinger, the FGM-148 Javelin, the RIM-116 RAM, and the AIM-9X Sidewinder. The CIWS laser adjunct could potentially “correct” this situation by laser heating target vehicles to enhance their signature to existing IR guided missiles. Note that this is NOT “conventional” semiactive-laser (SAL) guidance—the LaWS is not a coded illuminator, nor do the seekers in question rely on this coding. The IR missiles would be unmodified weapons taken from inventory. The LaWS adjunct would simply contribute laser energy that heats the target and enhances its signature for the missile. While, at the ranges envisioned, this laser heating alone would not be sufficient to “kill” the target, it could definitely heat the target. It should also be noted that the laser “illumination” could potentially be used to preferentially select a specific target from among a group of targets for engagement by a missile. It is expected that these engagements could occur at ranges of two to four times the effective Phalanx gun engagement ranges. Use of LaWS in this manner would be exactly analogous to the use of a SAL designator for a SAL guided missile, such as the AGM-114 Hellfire. It is expected that similar rules of engagement would apply.

Direct Target Destruction by Laser Heating

Some threats are known to be vulnerable to direct destruction by the application of laser energy for an appropriate period of time. The currently envisioned system would be able to destroy a subset of naval threats at ranges comparable to, and in some cases greater than, the ranges achieved with modern, stabilized guns using EO fire control systems and modern ammunition. In the case

of a LaWS adjunct, the addition of the laser would open new options for a firing/engagement doctrine and would be expected to conserve CIWS rounds for use on threats that are not appropriate for this laser power level. While the laser is often quoted as having an “unlimited magazine,” the true number of threats that can be engaged by the laser in any period of time is limited by the required illumination time and by the time required to evaluate a kill and transition to the next target. Thus, for particular target velocities and numbers, the “effective laser magazine” might be added to the CIWS magazine to increase the total number of targets engaged by the combined system.

LAWS ACCOMPLISHMENTS

A government/industry team, led by government technical personnel, have achieved significant accomplishments since the start of the LaWS program in 2007; specifically, the team:

- Conducted mission analyses
- Developed threat lethality estimates
- Performed industry surveys for critical components and subsystems
- Performed extensive trade-off analyses
- Designed a prototype system
- Constructed the system—the prototype director and mount (see Figure 3)
- Performed numerous laboratory-based tests of subsystems and the complete prototype
- Validated system operation with a full-up field test at high power using BQM-147A UAV target drones

Additionally, the team was able to minimize the cost of the prototype by leveraging hardware that had already been developed or procured for other applications, including an L3-Brashear tracking mount, a 50-cm telescope, and high-performance IR sensors. Some components were commercially procured, such as the 5.4-kW fiber lasers. Figure 4 shows three laser cabinets, containing two lasers apiece, resulting in a total power output of 32.4 kW. Other components, such as the beam combiner and much of the system software required for operation and target tracking, had to be specifically designed, fabricated, and tested.

The LaWS program achieved a highly successful field test/demonstration in June 2009 when the prototype successfully engaged and destroyed five drone targets at tactically significant ranges at the China Lake, California, test range (see Figure 5).

ADDITIONAL WORK TO BE DONE

Since the LaWS prototype sits on a dedicated gimbal, much additional work needs to be done



Figure 3. Photo of LaWS During Testing at the Naval Weapons Center, China Lake



Figure 4. IPG Laser Cabinets

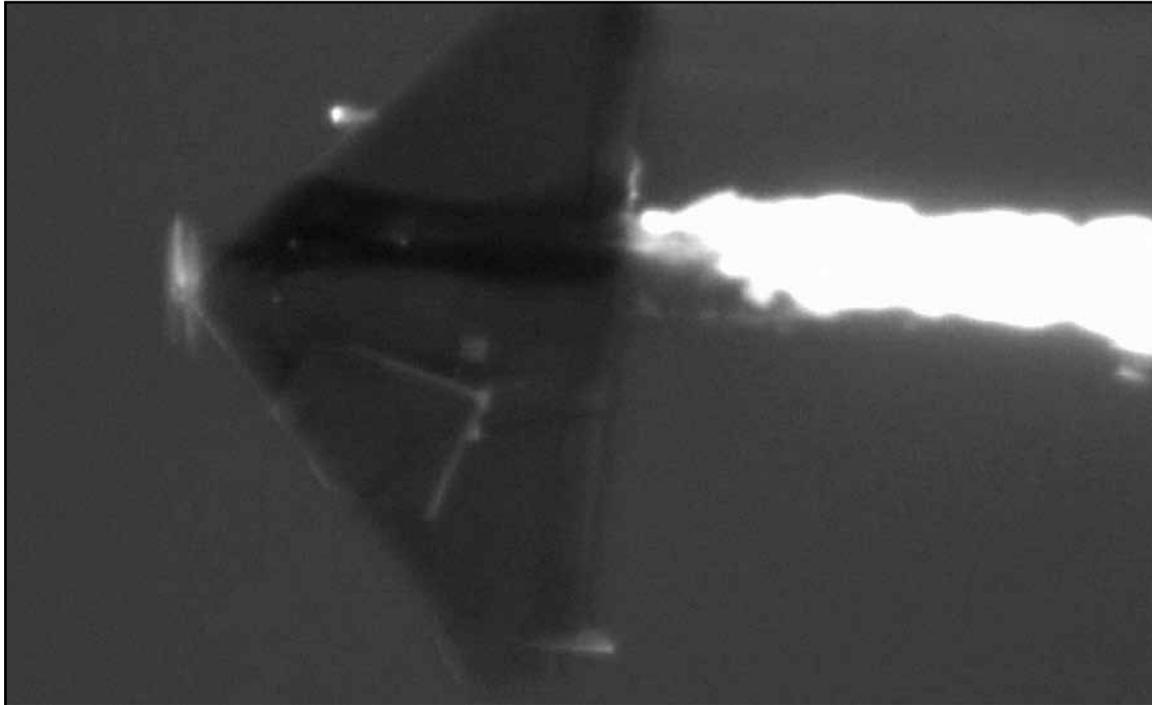


Figure 5. BQM-147A During LaWS Engagement

to place the weapon on the CIWS mount. The latter would require new control systems and optomechanical hardware for line-of-sight stabilization. Other aspects of the shipboard environment are also more stressful, and future mission areas may require an increasingly robust capability to deal with optical turbulence and the high-clutter environment of the ocean surface. Additional laser power might also be required. These modifications, depending on the level of capability desired, will require engineering modifications to the system. Engineering analysis and design to address these issues is currently underway at NSWCDD.

While the aforementioned engineering issues are important to address, there are additional technical issues that have yet to be analyzed. These issues are concerned with the potential utility of the system. Indeed, most of the detailed technical analyses and experiments performed thus far have focused on target destruction, with some effort expended on the issue of seeker damage/destruction. Developing credible lethality estimates for various potential threat targets is clearly very

important, but one consequence of the lethality focus is that necessary, detailed, defensible technical analysis, analytic model development, and experiments have not been performed to explore the other functions/features that a CIWS Adjunct LaWS might provide to the overall ship combat system. Some of these contributions might become “routine” if the LaWS were available.

For example, a hard-kill engagement of a target by a Navy shipboard weapon is a relatively rare event, even during wartime conditions. On the other hand, ships in combat zones—and elsewhere—constantly have the problem of detecting potential threats, tracking them, identifying them, determining their intent, and providing warning. Thus, use of the LaWS system, at less than its full lethal potential, could become a daily, standard practice. It is still not clear how these potential benefits and capabilities could be measured or quantified to the satisfaction of key decision makers.

Likewise, other potential advantages of laser weapons—such as the potential for precision engagement, covert engagement, fire starting, graduated lethality, low cost per shot, and “unlimited”

magazine—have not been subjected to rigorous technical analysis for feasibility, utility, and practicality. These investigations need to be performed and are gradually being addressed within the LaWS program.

Although the Phalanx CIWS system is currently installed on a number of Navy surface warships—either a single mount or a double mount—there are still significant numbers of ships that do not have a Phalanx system. It is highly desirable to make LaWS potentially available to virtually any ship that could benefit from the enhanced capabilities.

While the technical issues associated with the addition of LaWS to the Phalanx CIWS will be somewhat different from those associated with adding a LaWS system to other weapon systems—or the provision of a “stand-alone” LaWS—they do not appear to be insurmountable. For example, a LaWS beam director might be added to the stabilized Mk 38 Mod 2 25mm gun or the Mk 46 Mod 2 30mm gun. A LaWS beam director might be added to (or even substituted for) the Mk 46 EO Sight on DDGs or added to the trainable RAM launcher. Other options may exist as well.

The issue of defending combat logistics force ships, joint sealift ships, and certain support vessels from attacks from small boats or UAVs is also relevant. These ships often have little or no installed defensive capabilities for potential terrorist or pirate threats, and expeditionary security detachments do not have decisive warning or engagement capability. In addition, there are severe limitations placed on concept of operations (CONOPS) and rules of

engagement due to the limited objectives/limited means of the various missions.

A system such as LaWS could provide graduated lethality from warning to destruction. It also could provide additional applications to minimize risk to sea base platforms and enhance sea shield capabilities against nonstate threats. If acceptable rules of engagement can be established, the advantages of graduated lethality might be extended to ships in port or entering/exiting harbors.

While considerable additional work needs to be done to produce a tactical system, the LaWS program’s recent demonstration of capability provides strong evidence that a useful, tactical system could be produced within reasonable cost, volume, weight, and power constraints to provide the warfighter with a suite of additional tools to fight today’s and tomorrow’s wars.

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