Navy Shipboard Lasers: Background and Issues for Congress

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Summary

This report provides background information and issues for Congress on shipboard solid state lasers (SSLs) that the Navy is developing for surface-ship self-defense. The Navy's proposed FY2025 budget requests continued research and development funding for some of these efforts.

The Navy installed its first prototype SSL capable of countering surface craft and unmanned aerial vehicles (UAVs) on a Navy ship in 2014. The Navy since then has been developing and installing additional SSL prototypes with improved capability for countering surface craft and UAVs. Higher-power SSLs being developed by the Navy could have a capability for countering anti-ship cruise missiles (ASCMs). Current Navy efforts to develop SSLs include

- the Solid State Laser Technology Maturation (SSL-TM) effort;
- the Optical Dazzling Interdictor, Navy (ODIN);
- the Surface Navy Laser Weapon System (SNLWS) Increment 1, also known as the high-energy laser with integrated optical dazzler and surveillance (HELIOS); and
- the High Energy Laser Counter-ASCM Program (HELCAP).

The issue for Congress is whether to modify, reject, or approve the Navy's acquisition strategies and funding requests for shipboard laser development programs. Decisions that Congress makes on this issue could affect Navy capabilities and funding requirements and the defense technology and industrial base.

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Issue for Congress

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This CRS report supersedes an earlier CRS report that provided an introduction to potential Navy shipboard lasers.[1]

Earlier Coverage of EMRG and GLGP/HVP Programs

This CRS report previously included coverage of Navy efforts to develop two other potential shipboard weapons—the electromagnetic railgun (EMRG) and the gun-launched guided projectile (GLGP), also known as the hypervelocity projectile (HVP). As part of its FY2022 budget submission, the Navy proposed suspending further work on the EMRG and GLGP programs and requested no research and development funding for them. For background information on the EMRG and GLGP programs, see the April 1, 2022, version or earlier versions of this CRS report.[2]

CRS Reports on Other DOD Efforts to Develop Lasers

SSLs (and other directed energy weapons) are being developed by multiple parts of the Department of Defense (DOD), not just the Navy,[3] and have potential application to military aircraft and ground forces equipment, not just surface ships. Other CRS reports cover some of these other efforts.[4]

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[1] CRS Report R41526, *Navy Shipboard Lasers for Surface, Air, and Missile Defense: Background and Issues for Congress*, by Ronald O'Rourke. This earlier CRS report was archived following its final update on June 12, 2015, and remains available as a supplementary reference source on potential Navy shipboard lasers.

[2] The title of the April 1, 2022, version and earlier versions of this report was *Navy Lasers, Railgun, and Gun-Launched Guided Projectile: Background and Issues for Congress*.

[3] For a discussion of Army laser development programs, see CRS Report R45098, *U.S. Army Weapons-Related Directed Energy (DE) Programs: Background and Potential Issues for Congress*, by Andrew Feickert.

[4] See CRS In Focus IF11882, *Defense Primer: Directed-Energy Weapons*, by Kelley M. Sayler; CRS Report R46925, *Department of Defense Directed Energy Weapons: Background and Issues for Congress*, coordinated by Kelley M. Sayler; and CRS Report R45098, *U.S. Army Weapons-Related Directed Energy (DE) Programs: Background and Potential Issues for Congress*, by Andrew Feickert.

Background

Strategic and Budgetary Context

Concern About Survivability of Navy Surface Ships

Although Navy surface ships have a number of means for defending themselves against surface craft, unmanned aerial vehicles (UAVs), and anti-ship missiles,[5] some observers are concerned about the survivability of Navy surface ships in potential combat situations against adversaries, such as China, that are armed with large numbers of UAVs and anti-ship missiles, including advanced models.[6] Concern about this issue has led some observers to conclude that the Navy's surface fleet in coming years might need to avoid operating in waters that are within range of these weapons. Views on whether Navy surface ships can adequately defend themselves against UAVs and anti-ship missiles might influence perspectives on whether it would be cost effective to spend money on the procurement and operation of such ships.

Depth of Magazine and Cost Exchange Ratio

Overview

Two key limitations that Navy surface ships currently have in defending themselves against UAVs and anti-ship missiles are limited depth of magazine and unfavorable cost exchange ratios. Limited depth of magazine refers to the fact that Navy surface ships can use surface-to-air missiles (SAMs) and their Close-in Weapon System (CIWS) Gatling guns to shoot down only a certain number of enemy UAVs and anti-ship missiles before running out of SAMs and CIWS ammunition[7]—a situation (sometimes called "going Winchester") that can require a ship to

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[5] These include the following: operating ships in ways that make it hard for others to detect and accurately track Navy ships; jamming or destroying enemy targeting sensors; interfering with the transmission of targeting data from sensors to weapon launchers; attacking missile launchers (which can be land-based launchers, ships, submarines, or aircraft); and countering missiles and UAVs headed toward Navy ships. Navy measures for countering missiles and UAVs headed toward Navy ships include the following: jamming a missile's or UAV's sensor or guidance system; using decoys of various kinds to lure enemy missiles away from Navy ships; and shooting down enemy missiles and UAVs with surface-to-air missiles and the Phalanx Close-In Weapon System (CIWS), which is essentially a radar-controlled Gatling gun. Employing all these measures reflects a long-standing Navy approach of creating a multi-layered defense against enemy missiles, and of attacking the enemy's "kill chain" at multiple points so as to increase the chances of breaking the chain. (The kill chain is the sequence of steps that an enemy must complete to conduct a successful missile attack on a Navy ship. Interfering with any step in the sequence can break the kill chain and thereby prevent or defeat the attack.)

[6] For more on China's anti-ship missiles and UAVs, see CRS Report RL33153, *China Naval Modernization: Implications for U.S. Navy Capabilities—Background and Issues for Congress*, by Ronald O'Rourke. Enemy missiles are not the only reasons that some observers are concerned about the future survivability of U.S. Navy surface ships in combat situations; observers are also concerned about threats to U.S. Navy surface ships posed by small boats, mines, and torpedoes.

[7] Navy cruisers have 122 missile cells; Navy destroyers have 90 or 96 missile cells. Some of these cells are used for storing and launching Tomahawk land attack cruise missiles or anti-submarine rockets. The remainder are available for storing and launching SAMs. A Navy cruiser or destroyer might thus be armed with a few dozen or several dozen SAMs for countering missiles and UAVs. Countering missiles and UAVs with SAMs might sometimes require shooting two SAMs at each enemy missile.

withdraw from battle, spend time travelling to a safe reloading location (which can be hundreds of miles away),[8] and then spend more time traveling back to the battle area.

Unfavorable cost exchange ratios refer to the fact that a SAM used to shoot down a UAV or anti-ship missile can cost the Navy more (perhaps much more) to procure than it cost the adversary to build or acquire the UAV or anti-ship missile. Procurement costs for Navy air-defense missiles range from several hundred thousand dollars to a few million dollars per missile, depending on the type. In combat scenarios against an adversary with a limited number of UAVs or anti-ship missiles, an unfavorable cost exchange ratio can be acceptable because it saves the lives of Navy sailors and prevents very expensive damage to Navy ships. But in combat scenarios (or an ongoing military capabilities competition) against a country such as China that has many UAVs and anti-ship missiles and a capacity for building or acquiring many more, an unfavorable cost exchange ratio can become a very expensive—and potentially unaffordable—approach to defending Navy surface ships against UAVs and anti-ship missiles, particularly in a context of constraints on U.S. defense spending and competing demands for finite U.S. defense funds.

SSLs offer a potential for dramatically improving depth of magazine and the cost exchange ratio:

- **Depth of magazine.** SSLs are electrically powered, drawing their power from the ship's overall electrical supply, and can be fired over and over, indefinitely, as long as the laser continues to work and the ship has fuel to generate electricity.
- **Cost exchange ratio.** Depending on its beam power, an SSL can be fired for an estimated marginal cost of $1 to less than $10 per shot (much of which simply is the cost of the fuel needed to generate the electricity used in the shot).[9]

SSLs that have enough beam power to counter small boats and UAVs, but not enough to counter anti-ship cruise missiles (ASCMs), could nevertheless indirectly improve a ship's ability to counter ASCMs by permitting the ship to use fewer of its SAMs for countering UAVs, and more of them for countering ASCMs.

Navy Operations in Red Sea and Gulf of Aden Since October 2023 Have Spotlighted Depth of Magazine and Cost Exchange Ratio

Operations by U.S. and allied warships ships in the Red Sea and the Gulf of Aden since October 2023 to defend commercial cargo ships (and themselves) from attacks by Houthi forces in Yemen using drones, cruise missiles, and ballistic missiles[10] have spotlighted the above-discussed considerations of depth of magazine and cost exchange ratios, particularly for shooting down substantial numbers of drones, and have drawn attention to the potential ability of lasers (and high-power microwave [HPM] weapons)[11] to counter drones while using fewer of a ship's finite

[8] The missile cells on a Navy cruiser or destroyers are clustered together in an installation called a Vertical Launch System (VLS). VLS cells cannot be reloaded while the ship is underway; a ship needs to return to a port or a calm anchorage to reload its VLS.

[9] Source: Navy information paper on shipboard lasers dated October 20, 2021, provided to CRS by Navy Office of Legislative Affairs on November 17, 2021.

[10] For general background on these attacks, see CRS Insight IN12301, *Houthi Attacks in the Red Sea: Issues for Congress*, by Jeremy M. Sharp.

[11] For more on HPM weapons, see CRS In Focus IF11882, *Defense Primer: Directed-Energy Weapons*, by Kelley M. Sayler; CRS Report R46925, *Department of Defense Directed Energy Weapons: Background and Issues for Congress*, coordinated by Kelley M. Sayler.

number of air-defense missiles and with a more favorable (i.e., more affordable) cost exchange ratio.[12]

On February 13, 2024, the Chief of Naval Operations, Admiral Lisa Franchetti, reportedly stated that as of that date, five Navy destroyers operating in the area had collectively shot down 14 anti-ship ballistic missiles (ASBMs), 7 cruise missiles, and more than 70 drones—a total of more than 91 targets—and that the shootdowns of the ASBMs were the Navy's first in an operational (as opposed to a development or test) setting.[13] Many of these 91-plus shootdowns might have been done with SAMs; some might have involved the use of more than one SAM for an individual target (so as to help ensure that the target would be shot down); and additional SAMs might have been used in engagements other than the 91-plus listed above (i.e., engagements in which the targets were not shot down).

A February 18, 2024, news broadcast stated: "We learned that so far, the Navy has fired more than 100 of their Standard surface-to-air missiles, that can cost as much as $4 million each."[14]

An April 16, 2024, press report states

> The U.S. Navy is nearly $1 billion in the hole after defending Israel from Iranian missiles last weekend and fighting off Houthi attacks on Red Sea shipping since October, the service's secretary said Tuesday [April 16] in a bid to convince House lawmakers to approve $95 billion in supplemental funding.
>
> "I would argue that the President's budget numbers are adequate, but that's also prior to the attacks that we've just had this weekend alone, for example. So we are now closely approaching $1 billion in expenditures for munitions that we need paid back by the

[12] See, for example, Brad Dress, "Houthi Fight Extracts Heavy Cost from Pentagon," *The Hill*, March 2, 2024; Todd South, "Cost Drain and Weapon Stockpile Drawdowns Worry Marine General," *Marine Corps Times*, February 16, 2024; Justin Katz, "Munitions Stockpile Issue Persists 2 Years into Ukraine Conflict: Marine Corps General," *Breaking Defense*, February 14, 2024; Wes Rumbaugh, "Cost and Value in Air and Missile Defense Intercepts," Center for Strategic and International Studies (CSIS), February 13, 2024; Brad Howard, "How Chaos in the Red Sea Is Putting the U.S. Navy to the Test," *CNBC*, January 24 (updated January 25), 2024; Colin Demarest, Megan Eckstein, and Geoff Ziezulewicz, "Amid Red Sea Clashes, Navy Leaders Ask: Where Are Our Ship Lasers?" *Defense News*, January 22, 2024; Geoff Ziezulewicz, "What the Navy Is Learning from Its Fight in the Red Sea," *Military Times*, January 18, 2024; Eugene Gholz, "The US Military Role in the Red Sea—Now Turning Offensive—Is a Bad Deal," Cato Institute, January 12, 2024; Rudy Ruitenberg, "French Navy Defends Use of Million-Euro Missiles to Down Houthi Drones," *Defense News*, January 11, 2024; Rich Abott, "SWO BOSS Wants Accelerated Directed Energy Weapons," *Defense Daily*, January 9, 2024; Sam LaGrone, "New SWOBOSS Wants More Directed Energy Weapons on Warships as Low-Cost Threats Expand," *USNI News*, January 9, 2024; Nick Wilson, "Navy Looks to Field Directed-Energy Weapons to Counter Increasingly Cheap and Prevalent Drones," *Inside Defense*, January 9, 2024; Brad Lendon, "How US Warships Are Shooting Down Houthi Drones in the Red Sea, and What Might Come Next," *CNN*, December 20, 2023; Doug Cameron, "Pentagon Eyes Microwave Weapons to Tackle Drone Threat," *Wall Street Journal*, December 19, 2020; Lara Seligman and Matt Berg, "A $2M Missile vs. a $2,000 Drone: Pentagon Worried over Cost of Houthi Attacks," *Politico*, December 19 (updated December 20), 2023.

[13] Geoff Ziezulewicz, "Why the Navy Says Its Red Sea and Gulf of Aden Battles Are Historic," *Military Times*, February 13, 2024. See also Jonathan Lehrfeld, Diana Stancy, and Geoff Ziezulewicz, "All the Houthi-US Navy Incidents in the Middle East (That We Know Of)," *Military Times*, February 12, 2024. Bernat Armangue and Tara Copp, "On the USS Eisenhower, 4 Months of Combat at Sea Facing Houthi Missiles and a New Sea Threat," Associated Press, February 15, 2024, which states that "as of Wednesday [February 14], the carrier strike group—which includes the cruiser USS Philippine Sea, the destroyers USS Mason and Gravely, and additional U.S. Navy assets in the region, including the destroyers USS Laboon and USS Carney—has conducted more than 95 intercepts of drones, anti-ship ballistic missiles and anti-ship cruise missiles…."

For more on the Navy's ballistic missile defense program, see CRS Report RL33745, *Navy Aegis Ballistic Missile Defense (BMD) Program: Background and Issues for Congress*, by Ronald O'Rourke.

[14] Norah O'Donnell, "Navy Counters Houthi Red Sea Attacks in Its First Major Battle at Sea of the 21st Century," *60 Minutes (CBS News)*, February 18 (updated June 23), 2024. See also Joseph Trevithick, "Navy Has Fired Around 100 Standard Series Missiles At Houthi Drones, Missiles: Report," *The War Zone*, February 19, 2024.

> supplemental," Carlos Del Toro told senators during a Senate Appropriations [Defense] subcommittee hearing.
>
> "We've been firing SM-2s, we've been firing SM-6s, and—just over the weekend—SM-3s to actually counter the ballistic missile threat that's coming from Iran. So we need this supplemental to pass this week," Del Toro said.[15]

An April 25, 2024, press report states

> The price tag for weapons and munitions used to destroy drones must come down, as the costs are "getting too expensive" and uncrewed systems are expected to saturate battlefields, according to the Pentagon's acquisition boss….
>
> Bill LaPlante, the undersecretary of defense for acquisition and sustainment, said April 24 during a conference hosted by the Center for Strategic and International Studies think tank in Washington that "cost curve matters" in counter-drone operations.
>
> The goal is to get the cost down to approximately tens of thousands of dollars per round, he added, noting a price exceeding $100,000 a shot is "getting too expensive."[16]

A May 1, 2024, press report states

> Downing Iranian-supplied missiles and drones with multi-million dollar SM-2 [Standard Missile 2] missiles to protect shipping in the Red Sea and Gulf of Aden is a bad exchange that must change, the vice chairman of the Joint Chiefs of Staff said Wednesday [May 1].
>
> "It has been an air-defense fight" in which the Navy and Air Force, along with allies and partners in Operation Prosperity Guardian, have largely prevailed in demonstrating "how we bring defense in depth," Adm. Christopher Grady said during a U.S. Naval Institute-CSIS Maritime Security Dialogue.
>
> To change the cost-benefit equation, he wants more directed energy systems deployed "where a drop of fuel becomes a weapon" to destroy attacking unmanned systems.[17]

A May 15 2024, press report stated

> The toll of expending expensive surface fleet weapons to take out cheap Houthi drones, anti-ship ballistic and cruise missiles in the Red Sea has pushed the US Navy to speed its exploration of cheaper alternatives and "disruptive capabilities" like Replicator drone swarms that the service hopes could do the job much more cheaply, according to one of the Navy's most senior officials.
>
> The navy "absolutely" needs to invest in cheaper equipment to down drones, said Rear Adm. Fred Pyle, director of surface warfare, during a discussion at the Center for Strategic and International Studies in Washington on Tuesday [May 14].
>
> "We're working towards that end, and we have some solutions that I can't go into, but we are going to get after finding more cost-effective ways to address those lower-end threats,"

[15] Lauren C. Williams, "Mideast Missile Duels Have Cost US Navy Nearly $1B, Secretary Says," *Defense One*, April 16, 2024. See also Svetlana Shkolnikova, "Navy Seeks Urgent Replenishment of $1B in Munitions Spent Countering Iran-Led Attacks in Middle East," *Stars and Stripes*, April 16, 2024; Nick Wilson, "SECNAV: Navy Needs Supplemental to Replace Nearly $1 Billion in Expended Munitions," *Inside Defense*, April 16, 2024.

[16] Colin Demarest, "Drone-Killing Costs Must Come Down, Says Pentagon's Chief Weapons Buyer," *C4ISRNet*, April 25, 2024. See also Nicholas Slayton, "US Needs Cheaper Ways to Shoot Down Drones, Pentagon Acquisition Chief Says," *Task & Purpose*, April 28, 2024.

[17] John Grady, "Navy Air Defense Mission in the Red Sea Makes Case for Directed Energy Weapons, Says VCJCS Grady," *USNI News*, May 1, 2024.

> he explained, later singling out the Pentagon's new, secretive Replicator as one example of an initiative developing that "more cost-effective" technology.[18]

A May 16, 2024, press report stated

> The Navy will increase funding for directed energy solutions, like lasers, to reduce the cost of intercepting enemy missiles, service secretary Carlos Del Toro said Thursday [May 16]—a month after he told lawmakers that shooting down drones and missiles in the Red Sea had cost the service nearly $1 billion. And, Del Toro said, he wants to see "aggressive" deployment in five to 10 years….
>
> In March, U.S. Central Command leader Gen. Erik Kurilla told lawmakers: "I would love to have the Navy produce more directed energy that can shoot down a drone so I don't have to use an expensive missile to shoot it down. But what's worse than not having that expensive missile shoot it down is hitting that $2 billion ship with 300 sailors on it."…
>
> When [Senator Angus] King asked Del Toro [at a hearing before the Senate Armed Services Committee on the Department of the Navy's FY2025 budget] if the Navy could commit to increasing its fund for directed energy research, the Navy secretary said yes, with a caveat.
>
> "To the extent that I have authority to do so in POM 2026,[19] I will absolutely do so…I thought that we needed to invest far more significantly in laser and high directed energy systems. I regret that we haven't done that for the past 30 years or so. We need to do that moving forward. There's no question in my mind to get to a place perhaps five to 10 years from now where we could actually start aggressively employing those capabilities on our ships early."[20]

A July 15, 2024, U.S. Navy news release stated that during combat operations in the Middle East from November 2023 to June 2024, ships from a U.S. Navy aircraft carrier strike group led by the aircraft carrier *Dwight D. Eisenhower* (CVN-69) launched 155 standard missiles (though not all of these were necessarily used for countering missiles or unmanned air, surface, or underwater vehicles), and that carrier-based aircraft from the strike group expended nearly 60 air-to-air missiles.[21]

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[18] Tim Martin, "High Price of Red Sea Shootdowns Speeds Navy's Pursuit of 'Cost-Effective' Solutions," *Breaking Defense*, May 15, 2024. See also Abby Shepherd, "Cost-Effective Method of Battling Houthis Poses Challenge, Pyle Says," *Inside Defense*, May 14, 2024.

[19] This is a reference to the Program Objective Memorandum 2026—an internal DOD document used for preparing DOD's FY2026 budget submission, which will be submitted to Congress in 2025.

[20] Patrick Tucker, "Navy Secretary Vows More Money for Anti-Drone Lasers," *Defense One*, May 16, 2024.

[21] U.S. Navy, "Unprecedented: Dwight D. Eisenhower Carrier Strike Group Returns from Combat Deployment," news release dated July 15, 2024, which states: "In total, IKECSG [Eisenhower (aka Ike) Carrier Strike Group] warships launched 155 standard missiles, and 135 TLAMs [Tomahawk land-attack cruise missiles] from their vertical launch system across self-defense and pre-planned strikes. IKECSG aircraft expended nearly 60 air-to-air missiles and released 420 air-to-surface weapons."

See also Wes Rumbaugh, "Did the U.S. Defense of Israel from Missile Attacks Meaningfully Deplete Its Interceptor Inventory?" Center for Strategic and International Studies (CSIS), December 4, 2024; Chris Panella and Jake Epstein, "The Navy's Top Ballistic Missile Interceptor Comes with a Heavy Price Tag, But the US Can't Afford to Go to War Without It," *Business Insider*, November 2, 2024; Jake Epstein, "The U.S. Navy Fired Nearly $2 Billion in Weapons Over a Year of Fighting in the Middle East," *Business Insider*, October 31, 2024; Nancy A. Youssef and Gordon Lubold, "Pentagon Runs Low on Air-Defense Missiles as Demand Surges," *Wall Street Journal*, October 29, 2024; Jake Epstein and Chris Panella, "The US Navy Is Burning Through Missiles in the Middle East that It Would Need in a War With China," *Business Insider*, October 11, 2024; Jake Epstein, "A US Navy Carrier Strike Group and a Few Other Warships Fired $1.16 Billion in Weapons Battling the Houthis in the Red Sea," *Business Insider*, August 28, 2024; Patrick Tucker, "Navy Still Bullish on Lasers But Widely-Deployed Directed-Energy Ship Defense Remains (continued...)

Navy Shipboard Solid State Lasers (SSLs) in General

Overview

The Navy in recent years has leveraged both significant advancements in industrial SSLs and decades of research and development work on military lasers done by other parts of DOD to make substantial progress toward deploying high-energy lasers (HELs)[22] on Navy surface ships. Navy surface ships would use high-energy SSLs initially for jamming or confusing (i.e., "dazzling") intelligence, surveillance, and reconnaissance (ISR) sensors, for countering small boats and UAVs, and potentially in the future for countering enemy anti-ship missiles as well. High-energy SSLs on Navy ships would generally be short-range defensive weapons—they would generally counter targets at ranges of about one mile to perhaps eventually a few miles.

In addition to a low marginal cost per shot and deep magazine, potential advantages of shipboard lasers include fast engagement times, an ability to counter radically maneuvering missiles, an ability to conduct precision engagements, and an ability to use lasers for graduated responses ranging from detecting and monitoring targets to causing disabling damage. Potential limitations of shipboard lasers relate to line of sight; atmospheric absorption, scattering, and turbulence (which prevent shipboard lasers from being all-weather weapons); an effect known as thermal blooming that can reduce laser effectiveness; countering saturation attacks; possible adversary use of hardened targets and countermeasures; and risk of collateral damage, including damage to aircraft and satellites and permanent damage to human eyesight, including blinding. These potential advantages and limitations are discussed in greater detail in the **Appendix**.

Earlier Developments

Earlier developments in the Navy's efforts to develop high-energy SSLs include the following:

- Between 2009 and 2012, the Navy successfully tested a prototype SSL called the Laser Weapon System (LaWS) against UAVs in a series of engagements that took place initially on land and subsequently on a Navy ship at sea. LaWS had a reported beam power of 30 kilowatts (kW).[23]
- Between 2010 and 2011, the Navy tested another prototype SSL called the Maritime Laser Demonstration (MLD) in a series of tests that culminated with an MLD installed on a Navy ship successfully engaging a small boat.
- In August 2014, the Navy installed LaWS on the USS *Ponce* (pronounced pon-SAY)—a converted amphibious ship that operated in the Persian Gulf as an interim Afloat Forward Staging Base (AFSB[I])[24]—to conduct evaluation of

Years Away," *Defense One*, August 8, 2024; Frank Wolfe, "Laser and Non-Kinetic Advances Sought by 5th Fleet," *Defense Daily*, August 8, 2024.

[22] In discussions of potential Navy shipboard lasers, a high-energy laser is generally considered to be a laser with a beam power of at least 10 kilowatts (kW). In addition to developing SSLs, the Navy has also performed research and development work on a different kind of laser, called the free electron laser (FEL). For background information on the FEL, see CRS Report R41526, *Navy Shipboard Lasers for Surface, Air, and Missile Defense: Background and Issues for Congress*, by Ronald O'Rourke.

[23] See, for example, Mike McCarthy, "Navy Authorized to Use Ship-Based Laser in Battle," *Defense Daily*, December 11, 2014: 3.

[24] As an interim AFSB, *Ponce* operated in the Persian Gulf as a "mother ship" for Navy helicopter and small boat operations. Ships referred to as AFSBs are now referred to as Expeditionary Sea Base ships (ESBs).

shipboard lasers in an operational setting against swarming boats and swarming UAVs (**Figure 1** and **Figure 2**).

- In December 2014, the Navy declared LaWS on the *Ponce* to be an "operational" system.[25] *Ponce* remained in the Persian Gulf until it was relieved in September 2017 by its replacement, the new-construction Expeditionary Sea Base ship *Lewis B. Puller* (ESB-3). *Ponce* returned to the United States and was decommissioned in October 2017, at which point LaWS was removed from Ponce. LaWS was to be refurbished to serve as a land-based test asset for the HELIOS effort discussed below.[26]

Figure 1. Laser Weapon System (LaWS) on USS *Ponce*

Source: Navy photograph dated November 16, 2014, accompanying David Smalley, "Historic Leap: Navy Shipboard Laser Operates in Arabian Gulf," *Navy News Service*, December 10, 2014.

[25] Mike McCarthy, "Navy Authorized to Use Ship-Based Laser in Battle," *Defense Daily*, December 11, 2014: 3; Sam LaGrone, "U.S. Navy Allowed to Use Persian Gulf Laser for Defense," *USNI News*, December 10, 2014; Philip Ewing, "Navy Declares Laser Weapon 'Operational,'" *Politico Pro (Pro Defense Report)*, December 10, 2014; Statement of Rear Admiral Mathias W. Winter, United States Navy, Chief of Naval Research, Before the Emerging Threats and Capabilities Subcommittee of the House Armed Services Committee on The Fiscal Year 2017 Budget Request, February 24, 2016, p. 15.

[26] Source: Navy briefing to CRS and the Congressional Budget Office (CBO) on SNLWS program, April 27, 2018. For additional discussion of LaWS, see U.S. Navy, *U.S. Navy Program Guide 2017*, pp. 180-181, which refers to LaWS as the SSL-QRC (solid state laser—quick reaction capability).

Development Roadmap

The Navy is developing SSLs with improved capability for countering surface craft and UAVs, and potentially an eventual capability for countering ASCMs. Navy efforts to develop these more capable lasers have included

- the Solid State Laser Technology Maturation (SSL-TM) effort;
- the Optical Dazzling Interdictor, Navy (ODIN);
- the Surface Navy Laser Weapon System (SNLWS) Increment 1, also known as the high-energy laser with integrated optical dazzler and surveillance (HELIOS); and
- the High Energy Laser Counter-ASCM Program (HELCAP).

Figure 2. Laser Weapon System (LaWS) on USS *Ponce*

Source: Navy photograph dated November 17, 2014, accompanying David Smalley, "Historic Leap: Navy Shipboard Laser Operates in Arabian Gulf," *Navy News Service*, December 10, 2014.

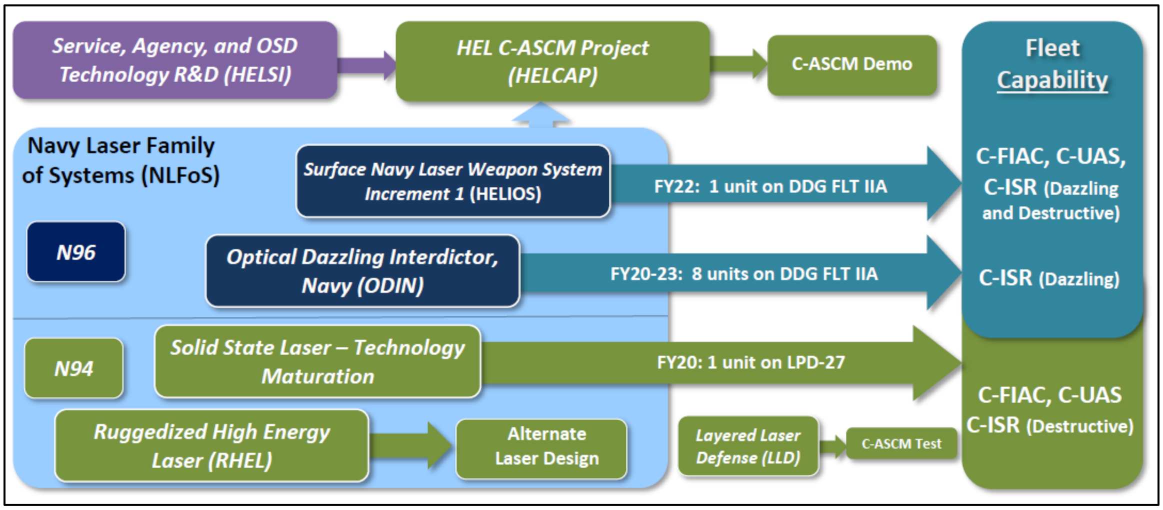
Figure 3 shows the Navy's approach for developing shipboard high-energy lasers as of May 16, 2024. As shown in **Figure 3**, first three efforts above are included in what the Navy calls the Navy Laser Family of Systems (NFLoS). (The fourth NFLoS effort shown in **Figure 3**, the Ruggedized High Energy Laser [RHEL] effort, is now completed.) **Figure 4** shows the Navy's approach for developing shipboard high-energy lasers as of August 17, 2022. Compared with the older **Figure 4** from August 2022, the newer **Figure 3** from May 2024 does not show SNLWS Increment 2 and SNLWS Increment 3 as future development efforts, and does not show an ASCM defense capability and a subsequent improved ASCM defense capability as future fleet capabilities.

Current and Recent Navy SSL Development Efforts

SSL-TM

The SSL Technology Maturation (SSL-TM) program developed a prototype shipboard laser called the Laser Weapons System Demonstrator (LWSD) "to address known capability gaps against asymmetric threats (UAS [unmanned aerial systems], small boats, and ISR sensors) and will inform future acquisition strategies, system designs, integration architectures, and fielding plans for laser weapon systems."[27] Industry teams led by BAE Systems, Northrop Grumman, and Raytheon, among others, competed to develop an LWSD with a beam power of up to 150 kW. On October 22, 2015, DOD announced that it had selected Northrop Grumman as the winner of the SSL-TM competition.[28]

Figure 3. Navy Laser Weapon Development Approach as of May 16, 2024



Source: Navy briefing slide provided by Navy Office of Legislative Affairs to CRS on May 16, 2024. N96 is the Surface Warfare Division of the Office of Chief of Naval Operations. N94 is the Innovation, Technology Missions, and Test and Evaluation Division.

The Navy announced in January 2018 that it intended to install LWSD on the amphibious ship *Portland* (LPD-27).[29] The system reportedly was installed on the ship in the fall of 2019.[30] On May 22, 2020, the Navy announced that *Portland* had used its LWSD to successfully disable a UAV in an at-sea test that was conducted on May 16, 2020.[31]

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[27] Department of Defense, *Fiscal Year (FY) 2024 Budget Estimates, Navy, Justification Book Volume 2 of 5, Research, Development, Test & Evaluation, Navy*, March 2023, p. 182 (PDF page 250 of 1568).

[28] DOD contract award announcements for October 22, 2015. See also "US Navy Selects Northrop Grumman to Design and Produce Shipboard Laser Weapon System Demonstrator," December 22, 2015. See also Richard Scott, "Northrop Grumman to Build on MLD for SSL Demonstrator," *IHS Jane's International Defence Review*, February 2016: 5; Michael Fabey and Kris Osborn, "Navy to Fire 150Kw Ship Laser Weapon from Destroyers, Carriers," *Scout Warrior*, January 23, 2017.

[29] Megan Eckstein, "LPD Portland Will Host ONR Laser Weapon Demonstrator, Serve as RIMPAC 2018 Flagship," *USNI News*, January 10, 2018; Richard Abott, "Next Navy Amphib Will Feature Laser Weapon Demo, Chosen as Flagship for RIMPAC 2018," *Defense Daily*, January 11, 2018.

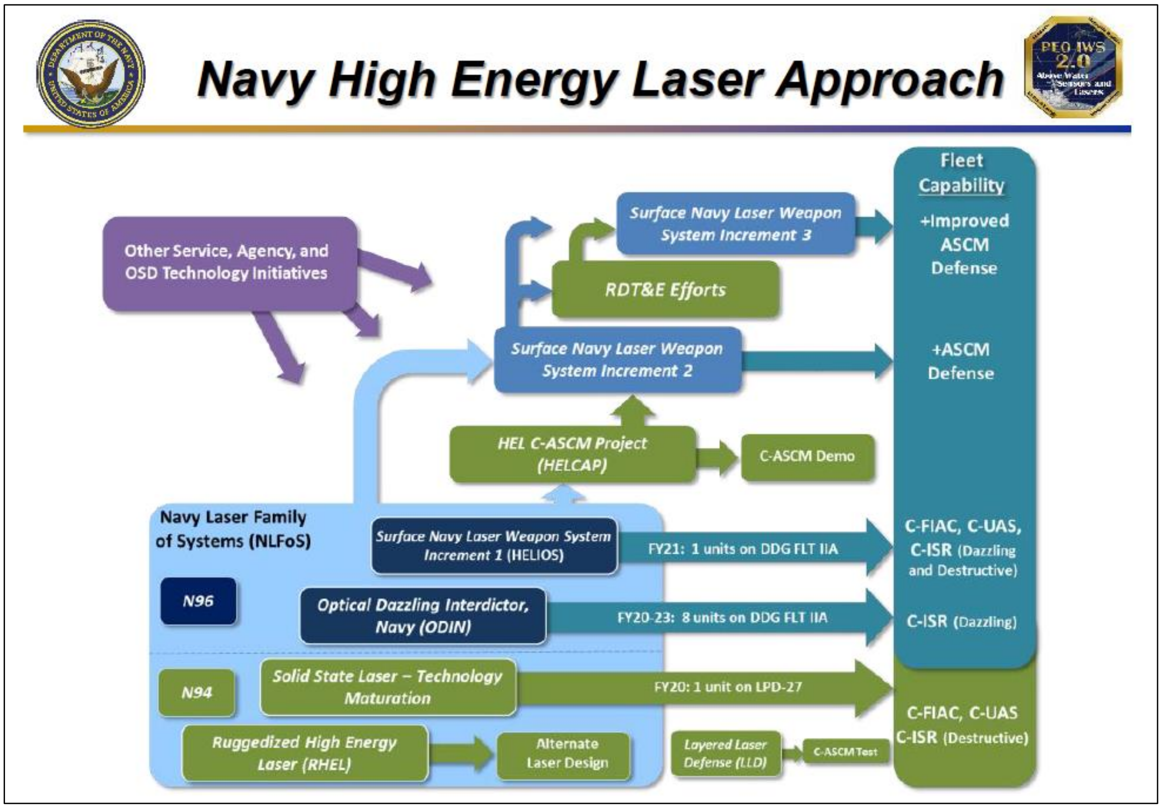
[30] Christopher P. Cavas, "Lasers Sprout in San Diego," *Defense & Aerospace Report*, March 1, 2020.

[31] Commander, U.S. Pacific Fleet Public Affairs, "USS Portland Conducts Laser Weapon System Demonstrator Test," (continued...)

Figure 5 is an Office of Naval Research (ONR) graphic illustration of the SSL-TM system and its components if it had been installed on the Navy's Self Defense Test Ship (the ex-USS *Paul F. Foster* [DD-964], an old Spruance [DD-963] class destroyer). **Figure 6** is a Navy graphic illustration of the SSL-TM system on *Portland*. An October 18, 2019, blog post included photographs (**Figure 7**, **Figure 8**, and **Figure 9**) of a device the blog post identified as the SSL-TM laser being transported from Redondo Beach to San Diego for installation on *Portland*.[32]

The Navy's FY2025 budget submission states that SSL-TM deinstallation, final report, program closeout, and hardware disposition began in the second quarter of FY2023 and are scheduled to be completed in the fourth quarter of FY2024.[33]

Figure 4. Navy Laser Weapon Development Approach as of August 17, 2022



Source: Navy briefing slide provided by Navy Office of Legislative Affairs to CRS on August 17, 2022. N96 is the Surface Warfare Division of the Office of Chief of Naval Operations. N94 is the Innovation, Technology Missions, and Test and Evaluation Division.

Navy News Service, May 22, 2020. See also Megan Eckstein, "VIDEO: USS Portland Fires Laser Weapon, Downs Drone in First At-Sea Test," *USNI News*, May 22, 2020; Paul McLeary, "US Warship Fries Drone with Powerful New Laser," *Breaking Defense*, May 22, 2020; Geoff Ziezulewicz, "Watch This Ship-Mounted Navy Laser Shoot Down a Drone," *Navy Times*, May 26, 2020.

[32] Tyler Rogoway, "Mysterious Object Northrop Is Barging from Redondo Beach Is a High-Power Naval Laser," *The Drive*, October 18, 2019.

[33] *Department of Defense, Fiscal Year (FY) 2025 Budget Estimates, Navy, Justification Book Volume 2 of 5, Research, Development, Test & Evaluation, Navy, Budget Activity 4,* March 2024, pp. 180, 185, 186 (PDF pages 256, 261, 262 of 1520).

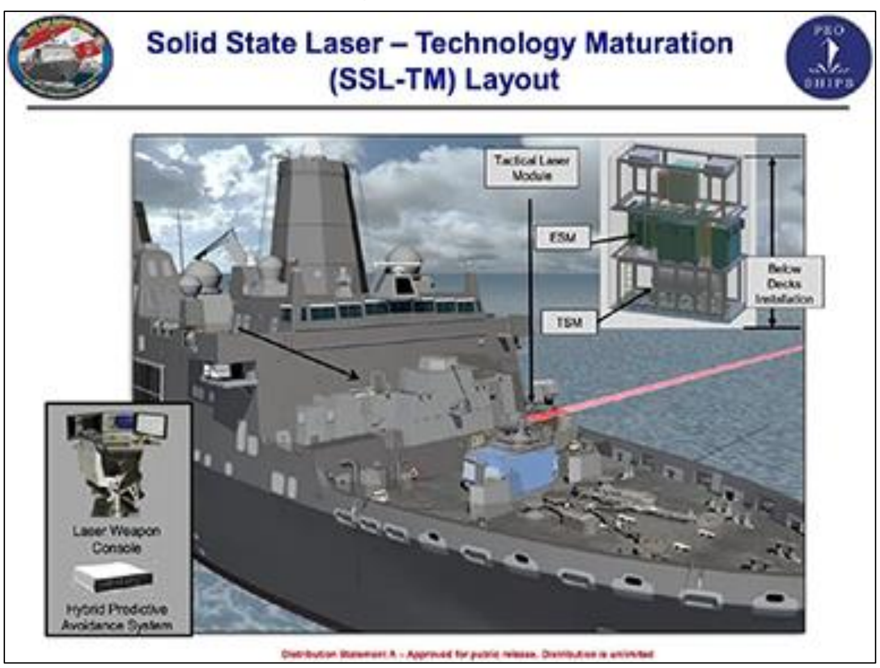
Figure 5. ONR Graphic of SSL-TM Laser System

Artist's rendering of installation on Navy's Self Defense Test Ship

Source: Slide from February 2016 ONR briefing to CRS on SSL-TM program, received from Navy Office of Legislative Affairs February 26, 2016.

Figure 6. Navy Graphic of SSL-TM Laser System

Artist's rendering of installation on USS *Portland*



Source: Navy briefing slide accompanying Tyler Rogoway, "Mysterious Object Northrop Is Barging from Redondo Beach Is a High-Power Naval Laser," *The Drive*, October 18, 2019. The blog post credits the slide to the Navy and describes it as a "recent slide."

Figure 7. Reported SSL-TM Laser Being Transported

Source: Photograph accompanying Tyler Rogoway, "Mysterious Object Northrop Is Barging from Redondo Beach Is a High-Power Naval Laser," *The Drive*, October 18, 2019. The photograph is a cropped version of a photograph printed in full elsewhere in the blog post. The uncropped version is credited to "Matt Hartman/ShoreAloneFilms.com."

Figure 8. Reported SSL-TM Laser Being Transported

Source: Photograph accompanying Tyler Rogoway, "Mysterious Object Northrop Is Barging from Redondo Beach Is a High-Power Naval Laser," *The Drive*, October 18, 2019. The photograph is credited to "KABC CH7 Screencap."

Figure 9. Reported SSL-TM Laser Being Transported

Source: Photograph accompanying Tyler Rogoway, "Mysterious Object Northrop Is Barging from Redondo Beach Is a High-Power Naval Laser," *The Drive*, October 18, 2019. The photograph is credited to "Matt Hartman/ShoreAloneFilms.com."

ODIN

Overview

Optical Dazzler Interdictor Navy (ODIN) systems have been installed on eight Arleigh Burke (DDG-51) class destroyers. **Figure 10** and **Figure 11** reportedly show an ODIN system. The first ODIN installation reportedly was done on the destroyer *Dewey* (DDG-105) in 2019.[34]

The Navy's FY2025 budget submission states

> Optical Dazzler Interdictor Navy (ODIN) development provides directed energy, shipboard Counter-Intelligence, Surveillance, and Reconnaissance (C-ISR) capabilities to the Fleet to dazzle Unmanned Aerial Systems (UASs) and other platforms that address the Urgent Operational Needs (UONs) statement provided by the Fleet. ODIN, as a non-Program of Record, was developed and fielded with RDT&E,N funding and was initially envisioned as a Non-Permanent Change (NPC). FY 2018 was the first year of funding which supported the design, development, procurement, and installation of 8 ODIN

[34] Hope Hodge Seck, "The Navy Has Installed the First Drone-Stopping Laser on a Destroyer," *Military.com*, February 21, 2020; Justin Katz, "Navy Installs Laser on Destroyer to Counter Unmanned Intelligence Drones," *Inside Defense*, February 21, 2020; Christopher P. Cavas, "Lasers Sprout in San Diego," *Defense & Aerospace Report*, March 1, 2020; Kris Osborn, "New Destroyer-Fired Laser Weapons Might Stop Hypersonic Missile Attacks," *Warrior Maven*, March 1, 2020, which was republished as Kris Osborn, "Could Naval Lasers Be the Solution to China's Hypersonic Missile Threat?" *National Interest*, March 7, 2020.

standalone units deployed on DDG 51 Flt IIA surface combatants. Eight (8) ODIN units are now operational in the Fleet.[35]

Figure 10. Reported ODIN System on USS *Stockdale*

Source: Photograph accompanying Brett Tingley, "Here's Our Best Look Yet at the Navy's New Laser Dazzler System," *The Drive*, July 13, 2021. The photograph as printed in the blog post includes the enlarged inset and the red arrow. The article credits the photograph (and a similar second photograph used for the inset) to the Navy.

Press Reports

A March 1, 2020, press report stated

> Little official information was available about the Dewey's system until Feb. 20, [2020,] when NAVSEA issued a release describing the Dewey's Optical Dazzling Interdictor, Navy (ODIN) system as "a laser weapon system that allows a ship to counter unmanned aerial systems."
>
> According to the release, the ODIN system was approved in early 2017 based on an urgent need requirement from US Pacific Command. It was developed by Naval Surface Warfare Dahlgren, Virginia and installed after two and half years. The system, NAVSEA said, "will be the first operational employment of the stand-alone system that functions as a dazzler. The system allows the Navy to rapidly deploy an important, new capability to the Navy's surface force in combating Unmanned Aircraft Systems (UAS) threats."
>
> ODIN is the first operational deployment of a laser dazzler, a Navy official said, adding that the stand-alone system is equipped with a laser that can temporarily degrade intelligence-0gathering capabilities of unmanned aerial systems.

[35] *Department of Defense, Fiscal Year (FY) 2025 Budget Estimates, Navy, Justification Book Volume 2 of 5, Research, Development, Test & Evaluation, Navy, Budget Activity 4,* March 2024, p. 951 (PDF page 1027 of 1520).

> Capt. Danny Hernandez, spokesman for the Navy's acquisition directorate, noted that the laser can "temporarily degrade intelligence-gathering capabilities of unmanned aerial systems," but he did not provide more information about the ODIN system, including its power, lethality and future plans….
>
> The NAVSEA release notes that, "within the next couple of years, the ODIN program will have all [ODIN] units operational within the fleet providing a safer and more technically advanced capability to the US Navy. Lessons learned from ODIN's installation on Dewey will inform installation on future vessels and further development and implementation of Surface Navy Laser Weapon Systems."…
>
> ODIN is not the first laser system fitted to the Dewey. A prototype LaWS system was installed on the ship's flight deck in 2012, but that system, also developed by ONR, was never intended to be permanent and was removed after tests.[36]

Figure 11. Reported ODIN System at Naval Support Facility Dahlgren

Source: Photograph accompanying Brett Tingley, "Here's Our Best Look Yet at the Navy's New Laser Dazzler System," *The Drive*, July 13, 2021. The caption to the photo states that it shows "OSIN being tested at Naval Support Facility Dahlgren [VA] in 2020." The article credits the photograph to the Navy.

A May 26, 2020, press report stated

> ODIN took just two and a half years for the Navy to move the system from an approved idea through design, construction and testing to actual installation aboard the Dewey—a notable achievement in defense program development.

[36] Christopher P. Cavas, "Lasers Sprout in San Diego," *Defense & Aerospace Report*, March 1, 2020. See also Kris Osborn, "New Destroyer-Fired Laser Weapons Might Stop Hypersonic Missile Attacks," *Warrior Maven,* March 1, 2020, which was republished as Kris Osborn, "Could Naval Lasers Be the Solution to China's Hypersonic Missile Threat?" *National Interest,* March 7, 2020.

> "The Pacific Fleet Commander identified this urgent counter-intelligence, surveillance and reconnaissance need, and the chief of naval operations directed us to fill it as quickly as possible," said Cmdr. David Wolfe, head of the directed energy program within the Integrated Warfare Systems program executive office.[37]

An April 7, 2021, press report states

> "ODIN is unique because it's a government-designed, -built, -tested, -installed system, which I think allowed us to go fairly quickly and meet that urgent need that came from the fleet," Rear Adm. Seiko Okano told USNI News last week.
>
> ODIN is already installed on three Arleigh Burke-class guided-missile destroyers and will be installed on two more this year and three more in the coming years, for a total of eight DDGs that will help test out the system during the course of their training and operations, Okano said.
>
> She said the ODIN capability is definitely something the Navy wants for the fleet—the ability to counter intelligence, surveillance and reconnaissance activities from an adversary by using a nonlethal dazzler against pesky drones, rather than shooting them down—but ODIN's current form factor won't be the final tool fielded broadly in the fleet.
>
> Testing aboard the eight destroyers will help ensure the whole operational sequence works—from the sailor detecting an unmanned aerial vehicle to targeting it with the dazzler to successfully rendering the UAV useless. That capability, once fully tested, will then be moved over to the HELIOS program [see next section] to serve as the "optical-dazzler" in the program's full name.[38]

SNLWS Increment 1 (HELIOS)

Overview

SNLWS Increment 1 is called HELIOS, an acronym meaning high-energy laser with integrated optical dazzler and surveillance. The HELIOS effort is focused on rapid development and rapid fielding of a 60 kW-class high-energy laser (with growth potential to 150 kW) and dazzler in an integrated weapon system, for use in countering UAVs, small boats, and ISR sensors, and for combat identification and battle damage assessment. In August 2022, it was reported that the first HELIOS system had been delivered to the Navy.[39] The system was installed on USS *Preble* (DDG-88).[40] **Figure 12** and **Figure 13** show renderings of HELIOS installed on a DDG-51.

The Navy's FY2025 budget submission states

> The High Energy Laser with Integrated Optical-Dazzler and Surveillance (HELIOS) system provides a low cost-per-shot capability to address Anti-Surface Warfare and Counter-Intelligence, Surveillance and Reconnaissance (C-ISR) gaps with the ability to dazzle and destroy Unmanned Aerial Systems (UAS) and defeat Fast Inshore Attack Craft (FIAC) while integrated into the AEGIS Combat System on a Flt IIA Destroyer. SNLWS

[37] Daniel P. Taylor, "The ODIN Shipboard Laser: Science Fiction No More," *Seapower*, May 26, 2020.

[38] Megan Eckstein, "Navy Installing More Directed Energy Weapons on DDGs, Conducting Land-Based Laser Testing This Year," *USNI News*, April 7, 2021.

[39] "Lockheed Martin Delivers Integrated Multi-Mission Laser Weapon System to the Navy," Lockheed Martin, August 18, 2022; Justin Katz, "Lockheed Delivers High-Energy Laser Four Years in the Making to US Navy," *Breaking Defense*, August 18, 2022; Rich Abott, "Lockheed Martin Delivers HELIOS Laser to Navy," *Defense Daily*, August 18, 2022; Seapower Staff, "Lockheed Martin Delivers Integrated Multi-Mission Laser Weapon System to the Navy," *Seapower*, August 22, 2022.

[40] Department of Defense, *Fiscal Year (FY) 2024 Budget Estimates, Navy, Justification Book Volume 2 of 5, Research, Development, Test & Evaluation, Navy*, March 2023, p. 971 (PDF page 1039 of 1568).

> provided an industry-developed and government integrated capability to the Fleet in as short a timeframe as possible, thereby addressing the NDS direction to foster a culture of innovation. SNLWS included the development of a laser weapon system in the 60 kW class. SNLWS leveraged technology available at that time to deliver an initial laser weapon system capability to the Fleet. Mk 5 Mod 0 HELIOS development leveraged the previous AN/SEQ-3 Laser Weapon System (LaWS) and the Mk 2 Mod 0 Laser Weapon System Demonstrator (LWSD) efforts.[41]

Figure 12. HELIOS System on DDG-51 Destroyer

Artist's rendering

Source: Lockheed Martin image taken from "Lockheed Martin Receives $150 Million Contract to Deliver Integrated High Energy Laser Weapon Systems to U.S. Navy," Lockheed Martin, March 1, 2018.

Press Reports

A March 21, 2019, press report states

> The Lockheed Martin [LMT] HELIOS will consist of a 60-150 kW single laser beam that can target unmanned aircraft systems (UAS) and small boats....
>
> The weapon will also feed intelligence, surveillance and reconnaissance (ISR) data into the ship's combat system and provide a counter-UAS (C-UAS) ISR dazzler capability. The dazzler uses a lower power setting to confuse or reduce ISR capabilities of a hostile UAS....
>
> The first HELIOS going on a destroyer will go on a Flight IIA [DDG-51 class] ship, but the Flight III [DDG-51 design] [h]as a downside [in] that it uses almost the same hull but focuses more [electrical] power generation on the new AN/SPY-6 Air and Missile Defense

[41] *Department of Defense, Fiscal Year (FY) 2025 Budget Estimates, Navy, Justification Book Volume 2 of 5, Research, Development, Test & Evaluation, Navy, Budget Activity 4,* March 2024, p. 936 (PDF page 1012 of 1520).

> Radar (AMDR). The AMDR will better detect air and missile threats, but [Rear Adm. Ron Boxall, director of Navy Surface Warfare said] "we are out of schlitz with regard to [electrical] power [in the Flight III design]. We used a lot of power for that [SPY-6 radar] and we don't have as much" extra for additional functions.
>
> Boxall said to get a HELIOS on a DDG-51 Flight III [ship], the Navy will have to either remove something or look at "very aggressive power management."...
>
> Last year, the Navy awarded Lockheed Martin a $150 million contract to develop two HELIOS systems in early 2018, with one to integrate on a DDG-51 and one for land-based testing….
>
> However, the FY '19 defense authorization bill restricted the Navy to only one HELIOS per fiscal year without first receiving a detailed contracting and acquisition strategy report.[42]

Figure 13. HELIOS System on DDG-51 Destroyer

Detail from artist's rendering

Source: Detail from Lockheed Martin image taken from "Lockheed Martin Receives $150 Million Contract to Deliver Integrated High Energy Laser Weapon Systems to U.S. Navy," Lockheed Martin, March 1, 2018.

On January 11, 2021, it was reported that Lockheed had delivered its production HELIOS laser to the Navy for installation on a DDG-51 Flight IIA destroyer later in 2021, and that Lockheed had found that the system is capable of providing not only self-defense (i.e., defense of the ship on

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[42] Rich Abott, "Navy to 'Burn The Boats' with Laser for Destroyer in 2021, Needs Bigger LSC for Lasers," *Defense Daily*, March 21, 2019. See also Sam LaGrone, "Navy Ready to 'Burn the Boats' with 2021 Laser Installation on a Destroyer," *USNI News*, March 20, 2019; Kyle Mizokami, "The Navy Plans to Put HELIOS Laser Weapon on Destroyer by 2021," *Popular Mechanics*, March 21, 2019; Justin Katz, "HELIOS Set for Critical Design Review in 2020, Delivery in May 2021," *Inside Defense*, May 2, 2019; Marc Selinger, "US Navy Tweaks Destroyer-Based Laser Effort," *Shephard Media*, May 8, 2019.

which it is installed) but also some degree of area defense (i.e., defense of other ships in the area).[43] A January 15, 2021, press report stated that HELIOS

> is slated to be permanently deployed aboard a Flight IIA DDG Arleigh Burke destroyer and integrated with its Aegis combat system....
>
> HELIOS is a 60-kilowatt solid-state laser capable of scalable effects, which can "dazzle" and blind sensors, but at high power it can "put a hole" through unmanned aerial vehicles, low flying aircraft, and in some cases, missiles, [Joe Ottaviano, Lockheed Martin business development director for advanced product solutions] said.
>
> Lockheed Martin went under contract to deliver the integrated system in 2018. It spent 2020 carrying out a critical design review and factory qualification tests.[44]

An April 7, 2021, press report states that

> [Rear Admiral Seiko Okano] said HELIOS began land-based testing a few weeks ago and will be installed on destroyer USS Preble (DDG-88) in December [2021].
>
> Unlike ODIN, which is a bolt-on capability, HELIOS is fully integrated into the ship's combat system and will be more complicated to install but also more capable due to the integration....
>
> Asked whether HELIOS will be the directed energy system of the future for the fleet or if it's too soon to tell, Okano said it will depend how lethal the laser beam proves to be during upcoming testing….
>
> [Okano] said the Navy is on a natural path to get there, increasing the capability of its directed energy systems with each new product it fields for testing—but it's unclear yet if HELIOS can go the distance and provide that cruise missile defense capability for the fleet or if it will be an intermediate step on the way to that final vision.[45]

A January 11, 2022, press report stated

> Lockheed Martin is preparing to send its latest directed energy weapon to San Diego for installation onboard an Arleigh Burke-class destroyer following successful testing at a Navy facility last year.
>
> Jeanine Matthews, a Lockheed Martin executive overseeing integrated warfare systems, told reporters today the High-Energy Laser with Integrated Optical-dazzler and Surveillance, dubbed HELIOS, completed several tests at Wallops Island, Va., in the fall. She said the company expects the weapon to be onboard the Preble (DDG 88) and out to sea later this year....
>
> Lockheed has been under contract to develop and produce HELIOS for three years and has a contract with the Navy that includes options for up to nine production units.[46]

An April 29, 2022, press report states

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[43] See for example, Rich Abott, "Lockheed Martin Delivers HELIOS to Navy, Boasts Additional Capability," *Defense Daily*, January 11, 2021; Jason Sherman, "Lockheed: HELIOS Laser Shows Early Potential for Area Defense; Exceeding Ship Self-Defense Objective," *Inside Defense*, January 11, 2021; Seapower Staff, "Lockheed Martin Delivers HELIOS Laser Weapon System to Navy for Testing," *Seapower*, January 11, 2021; Ed Adamczyk, "Lockheed Martin Delivers HELIOS Laser Weapon to U.S. Navy," *United Press International*, January 11, 2021.

[44] Stew Magnuson, "Navy to Fully Integrate Laser into Aegis Combat System (Updated)," *National Defense*, February 15, 2021.

[45] Megan Eckstein, "Navy Installing More Directed Energy Weapons on DDGs, Conducting Land-Based Laser Testing This Year," *USNI News*, April 7, 2021.

[46] Justin Katz, "Destroyer Preble to Get Lockheed High-Energy Laser in 2022," *Breaking Defense*, January 11, 2022.

> HELIOS laser system components are being prepped and shipped from Wallops Island, Virginia, to San Diego, California, to be integrated in Preble , according to Tyler Griffin, director of Lockheed Martin Advanced Product Solutions Strategy & Business development.
>
> The shipping and integration come after the system completes a series of tests at Wallops Island, Griffin told Janes during Navy League Sea-Air-Space 2022 Exposition at National Harbor, Maryland, during the first week of April.
>
> The tests culminated in October 2021 when the laser system "received a track of a challenging, high-speed target from the Aegis combat system, achieved optical track of the target, and engaged the target with a high-energy laser", he said. "This demonstration outcome effectively showcased the system has foundational capabilities against more stressing threats."
>
> The system arrived in Wallops in December 2020, he said.
>
> The 60 KW laser would be effective against UASs as well as small boats, he added. "If it's a UAV [unmanned aerial vehicle], you can dazzle it with a laser. With the aimpoint precision of the laser weapon system, the operator can aim for the UAV optical sensor. Or, if you want, you can bring the whole UAV down."[47]

HELCAP

The Navy's FY2025 budget submission states that the High Energy Laser Counter-ASCM Program (HELCAP)

> will expedite the development, experimentation, integration and demonstration of critical technologies to defeat crossing Anti-Ship Cruise Missiles (ASCM) by addressing the remaining technical challenges, e.g.: atmospheric turbulence, automatic target identification and aim point selection, precision target tracking with low jitter in high clutter conditions, advanced beam control, and higher power HEL development. HELCAP will assess, develop, experiment, and demonstrate the various laser weapon system technologies and methods of implementation required to defeat ASCMs in a crossing engagement….
>
> The HELCAP is an initiative that provides a flexible prototype system for government experimentation and demonstration of a high-energy laser system capable of defeating an anti-ship cruise missile. Key elements of the prototype system include the beam control testbed, 300 kW+ class laser source, prototype control system, and auxiliary prime power and cooling. The industry provider of the beam control testbed (developed under PE 0603801N) was selected through a competitive process and is being designed to accept technology insertion from other industry providers. The 300+ kW class laser source will be acquired by selecting one of the laser sources being developed under an Office of Secretary of Defense (OSD) laser scaling initiative and adapting it for transport and interface with the other elements of the prototype system. The Naval Surface Warfare Center Dahlgren (NSWCDD) will design and fabricate the control system and auxiliary prime power and cooling systems. NSWC DD government and contractor engineers will then integrate all above elements that make up the prototype and auxiliary systems and perform FY22-23 counter ASCM detect to defeat experimentation and demonstrations at government test sites.[48]

[47] Michael Fabey, "US Navy Accelerates Laser Acquisition, HELIOS Work Advances," *Jane's Navy International*, April 29, 2022.

[48] *Department of Defense, Fiscal Year (FY) 2025 Budget Estimates, Navy, Justification Book Volume 2 of 5, Research, Development, Test & Evaluation, Navy, Budget Activity 4,* March 2024, pp. 926, 928 (PDF pages 1002, 1004 of 1520).

Layered Laser Defense (LLD) System

An additional Navy laser development effort that is not shown in **Figure 3** is called the Layered Laser Defense (LLD) system. A March 9, 2020, DOD contract award announcement stated

> Lockheed Martin Corp., Baltimore, Maryland, is awarded a $22,436,852 letter contract for the integration, demonstration, testing and operation of the Layered Laser Defense (LLD) weapon system prototype onboard a Navy littoral combat ship [LCS] while that vessel is underway.… Key areas of work to be performed include development of a prototype structure and enclosure to protect the LLD from ships motion and maritime environment in a mission module format; system integration and test with government-furnished equipment; platform integration and system operational verification and test; systems engineering; test planning; data collection and analysis support; and operational demonstration. Work is expected to be complete by July 2021.[49]

A January 13, 2020, press report stated

> The Navy will put a laser weapon on a Littoral Combat Ship for the first time this year, amid efforts to boost the LCS's lethality and to develop and field a family of laser systems.
>
> USS Little Rock (LCS-9) will receive a laser weapon during its upcoming deployment, Commander of Naval Surface Forces Vice Adm. Richard Brown told reporters. The ship will likely deploy to U.S. 4th Fleet, where sister ship USS Detroit is currently operating.
>
> USNI News understands that Little Rock would be taking on a Lockheed Martin-made 150-kilowatt high energy laser, as part of a risk reduction effort between the company, the Office of Naval Research and the Program Executive Office for Integrated Warfare Systems. The effort would contribute to a larger layered laser defense effort, a source told USNI News.
>
> The laser weapon would aid the LCS in its surface warfare mission to counter fast-attack craft and unmanned aerial systems and detect incoming targets….
>
> A source told USNI News that, because Lockheed Martin makes the Freedom-variant LCS, it was able to design its 150kw laser with the right interfaces and margins in mind to make it compatible for this kind of at-sea LCS demonstration.[50]

An April 13, 2022, press report states

> The ground-based laser system homed in on the red drone flying by, shooting a high-energy beam invisible to the naked eye. Suddenly, a fiery orange glow flared on the drone, smoke poured from its engine and a parachute opened as the craft tumbled downward, disabled by the laser beam.
>
> The February [2022] demonstration marked the first time the U.S. Navy used an all-electric, high-energy laser weapon to defeat a target representing a subsonic cruise missile in flight.
>
> Known as the Layered Laser Defense (LLD), the weapon was designed and built by Lockheed Martin to serve as a multi-domain, multi-platform demonstration system. It can counter unmanned aerial systems and fast-attack boats with a high-power laser—and also use its high-resolution telescope to track in-bound air threats, support combat identification and conduct battle damage assessment of engaged targets.

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[49] Department of Defense, "Contracts for March 9, 2020." See also Rich Abott, "Lockheed Martin Nabs $22 Million Contract for Layered Laser Defense Prototype on LCS," *Defense Daily*, March 16, 2020.

[50] Megan Eckstein, "Littoral Combat Ship Will Field Laser Weapon as Part of Lockheed Martin, Navy Test," *USNI News*, January 13, 2020.

> The drone shoot-down by the LLD was part of a recent test sponsored by the Office of Naval Research (ONR) at the U.S. Army's High Energy Laser Systems Test Facility at White Sands Missile Range in New Mexico. The demonstration was a partnership between ONR, the Office of the Under Secretary of Defense (Research and Engineering) and Lockheed Martin....
>
> Although there's no plan to field the LLD, it offers a glimpse into the future of laser weapons. It is compact and powerful, yet more efficient than previous systems. It has specialized optics to observe a target and focus laser beams to maximum effect, while also incorporating artificial intelligence to improve tracking and targeting....
>
> During the recent test at White Sands, the LLD tracked or shot down an array of targets—including unmanned fixed-wing aerial vehicles, quadcopters and high-speed drones representative of subsonic cruise missiles.[51]

A January 18, 2023, press report states

> Lockheed Martin is developing a version of its Layered Laser Defense weapon system designed to be installed onboard a Littoral Combat Ship, and floating the capability as potentially part of a future upgrade program still being developed by the US Navy.
>
> The company worked with the Office of Naval Research last year to modify and package the laser so it could be installed onboard a ship and conducted test shots against targets at White Sands Missile Range, Chris Minster, program director for combatant ships, integration and test, told Breaking Defense last week during the Surface Navy Association's annual symposium.[52]

Navy Role in OUSD R&E High Energy Laser Scaling Initiative (HELSI)

Also not shown in **Figure 3** is the Navy's role in the Office of the Under Secretary of Defense for Research and Engineering's (OUSD R&E's) High Energy Laser Scaling Initiative (HELSI). DOD stated on April 28, 2020, that

> On April 10, 2020, the Department of Defense selected General Atomics as a third prime contractor to join previously selected prime contractors Lockheed Martin, and nLight/Nutronics in building high energy lasers for the High Energy Laser Scaling Initiative (HELSI). Each developer will produce a 300 kW class high energy laser (HEL) source prototype with an architecture scalable to 500 kW or beyond, using a unique technology approach. The focus is on common, multi-Service/Agency needs for HEL (high energy laser) improvements....
>
> Awards were made to the following:
>
> —nLight/Photonics [nLight/Nutronics], $48 million award: The performer will develop a 300 kW class HEL device based on coherent beam combined technology.
>
> —Lockheed-Martin, $83 million award: The performer will develop a spectral beam combined fiber laser prototype.

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[51] Warren Duffie, "Laser Trailblazer: Navy Conducts Historic Test of New Laser Weapon System," *Defense Visual Information Distribution Service (DVIDS)*, April 13, 2022. See also Justin Katz, "In Electric-Powered Laser Test, Navy Shoots Down Cruise Missile Analog," *Breaking Defense*, April 14, 2022; Steve Trimble, "Lockheed Laser Shoots Down Aerial Targets for U.S. Navy Demo," *Aviation Week*, April 14, 2022; Maritime Executive, "In a First, U.S. Navy Shoots Down Cruise Missile with a Laser System," *Maritime Executive*, April 18, 2022; Michael Fabey, "US Navy Accelerates Laser Acquisition, HELIOS Work Advances," *Jane's Navy International*, April 29, 2022.

[52] Justin Katz, "Lockheed Floats Laser Weapon LLD for Future LCS Upgrade Package," *Breaking Defense*, January 18, 2023.

> —General Atomics, $47 million: The performer will develop a distributed gain laser prototype.[53]

A September 15, 2022, press report states that within HELSI, "The Army has sponsored Lockheed Martin's 300-kilowatt laser, which will be used for the Indirect Fire Protection Capability-High Energy Laser (IFPC-HEL) program, while the other HELSI vendors include Nutronics Inc. sponsored by the Navy and General Atomics by the Air Force."[54]

Directed Energy Components for High Energy Lasers

The Navy's FY2023 budget submission included a new research and development project called Directed Energy Components for High Energy Lasers. The Navy's FY2025 budget submission states that this project

> Supports Industrial Base Analysis and Sustainment (IBAS) program efforts for the improvement of the production capability of the industrial base in order to produce Laser Weapon Beam Director (LWBD) components and sub-systems; reduce production lead times of Laser Weapon System Optics; improve quality and reduce production times of Fast Steering Mirror (FSM) and deformable mirrors….
>
> The effort will utilize Other Transaction Authority (OTA) vehicles in order to obtain personnel with the requisite experience and expertise required to develop the production capability enhancements. The successful OTA contractor(s) could be utilized as supplier(s) for these highly critical, difficult to manufacture components in future laser acquisition contracts.[55]

The Navy's FY2025 budget submission further states that the project "on track to complete in FY24."[56]

Remaining Development Challenges

In addition to achieving higher beam powers, developing high-energy SSLs for surface ship self-defense poses a number of other technical challenges. Skeptics sometimes note that proponents of high-energy military lasers over the years have made numerous predictions about when lasers might enter service with DOD, and that these predictions repeatedly have not come to pass. Viewing this record of unfulfilled predictions, skeptics have sometimes stated, half-jokingly, that "lasers are X years in the future—and always will be."

Laser proponents acknowledge the record of past unfulfilled predictions, but argue that the situation has now changed because of rapid advancements in SSL technology and a shift from earlier ambitious goals (such as developing megawatt-power lasers for countering targets at tens or hundreds of miles) to more realistic goals (such as developing kilowatt-power lasers for countering targets at no more than a few miles). Laser proponents might argue that laser skeptics

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[53] Department of Defense Research & Engineering Enterprise, "Defense Department Invests Additional $47 Million in High Energy Laser Scaling Initiative," April 28, 2022, accessed December 19, 2022, at https://rt.cto.mil/defense-department-invests-additional-47-million-in-high-energy-laser-scaling-initiative/, with the text of the statement continued at https://www.cto.mil/wp-content/uploads/2020/04/2020_Laser_Award_Announcement.pdf.

[54] Matthew Beinart, "Lockheed Martin Delivers 300KW Laser to DoD, Sees Opportunity for Power Beyond 500KW," *Defense Daily*, September 15, 2022.

[55] *Department of Defense, Fiscal Year (FY) 2025 Budget Estimates, Navy, Justification Book Volume 2 of 5, Research, Development, Test & Evaluation, Navy, Budget Activity 4,* March 2024, p. 946, 947 (PDF pages 1022, 1023 of 1520).

[56] *Department of Defense, Fiscal Year (FY) 2025 Budget Estimates, Navy, Justification Book Volume 2 of 5, Research, Development, Test & Evaluation, Navy, Budget Activity 4,* March 2024, p. 946 (PDF page 1022 of 1520).

are vulnerable to what might be called "cold plate syndrome" (i.e., a cat that sits on a hot plate will not sit on a hot plate again—but it will not sit on a cold plate, either).

A January 11, 2024, press report states

> The Navy and industry need to be more intellectually honest when discussing laser weapon systems, according to an admiral overseeing the technology's development. And speaking plainly and honestly about developing that tech, "It's hard," he added.
>
> "Sometimes we have a tendency to over promise and under deliver," Rear Adm. Fred Pyle told attendees at the Surface Navy Association's annual symposium on Wednesday. "We need to flip that to where, when we're intellectually honest, when we're honest with ourselves from a technology capability, that we have an agreed upon sight picture of what it's going to look like to deliver that capability."
>
> Speaking to reporters following his remarks onstage, Pyle added, "I can go back to the Arabian Gulf and probably 15 years ago, we had a ship called the Ponce that had a laser on it. … We're still working on that technology."…
>
> "We continue to invest in directed energy capabilities," Pyle said. "It requires space, weight, power and cooling, which can be a challenge on our current surface combatants."[57]

Issues for Congress

Issues for Congress regarding SSLs include the following:

- whether the Navy is moving too quickly, too slowly, or at about the right speed in its efforts to develop these weapons;
- the Navy's plans for transitioning SSLs from development to procurement and fielding of production models aboard Navy ships; and
- whether Navy the Navy's shipbuilding plans include ships with appropriate amounts of space, weight, electrical power, and cooling capacity to accommodate SSLs.

Potential oversight questions for Congress include the following:

- Using currently available air-defense weapons, how well could Navy surface ships defend themselves in a combat scenario against an adversary such as China that has or could have large numbers of UAVs and anti-ship missiles? How would this situation change if Navy surface ships in coming years were equipped with SSLs? How cost effective would SSLs be as surface ship self-defense weapons compared to other Navy surface ship self-defense measures?
- How significant are the remaining development challenges for SSLs?
- Does the Navy no longer intend to pursue SNLWS Increment 2 and SNLWS Increment 3 as future development efforts, or a laser-based ASCM defense capability, as might be suggested by **Figure 3** when compared to **Figure 4**? If that is the case, what was the basis for that change in intention?
- When does the Navy anticipate issuing a roadmap detailing its plans for procuring and installing production versions of SSLs on specific Navy ships by specific dates?

[57] Justin Katz, "'It's Hard': Navy Needs to Be Realistic About Laser Weapons, Admiral Says," *Breaking Defense*, January 11, 2024.

- Will the kinds of surface ships that the Navy plans to procure in coming years have sufficient space, weight, electrical power, and cooling capability to take full advantage of SSLs? What changes, if any, would need to be made in Navy plans for procuring large surface combatants (i.e., destroyers and cruisers) or other Navy ships to take full advantage of SSLs?

Regarding the issue of whether the Navy is moving too quickly, too slowly, or at about the right speed in its efforts to develop laser weapons, a February 15, 2023, press report states

> An Office of Naval Research (ONR) official this week said the Navy is moving "very cautiously" on directed energy (DE) laser weapons because the eventual first program of record could cost up to $1 billion.
>
> "The Navy is definitely interested. However, they are not at this point willing to press the ka-ching machine and get a lot of cash because it's going to be about a billion dollars, roughly give or take, to field the first true program of record laser. And that's why we've been experimenting so much," David Kiel, Director of the Directed Energy Warfare Office at ONR, said during a Feb. 14 panel at the annual WEST 2023 conference.[58]

Regarding efforts to transition lasers from research and development to procurement and installation of production models, an April 2023 Government Accountability Office (GAO) report on DOD directed energy programs states

> The Department of Defense (DOD) is currently developing directed energy weapons with the goal of defeating a range of threats, including drones and missiles. However, GAO found that, even as DOD makes progress developing these capabilities, its efforts to transition prototypes to acquisition programs face challenges.
>
> DOD and the military departments have efforts underway to develop directed energy weapons. For example, DOD and military departments developed multiple laser weapon system demonstrators and prototypes, which have been used in live fire demonstrations to successfully shoot down drones. DOD and the military departments are also developing higher-powered laser weapons to counter bigger threats. Additionally, the departments developed a range of high power microwave capabilities for purposes such as engaging missile or drone swarm attacks against a military base....
>
> However, DOD has long noted a gap—sometimes called "the valley of death"—between its development and its acquisition communities that impede technology transition. For example, the acquisition community may require a higher level of technology maturity than the development community is able to produce.
>
> For prototypes that a military department expects to eventually transition to a new or existing acquisition program, it needs to identify a transition partner that can support the further development of the new technology. To support transition, the Army developed a detailed plan describing schedules and stakeholder roles to build supporting activities around the use of directed energy weapons and early capabilities documents. However, while the Navy fielded several directed energy weapon prototypes and identified a potential transition partner, it does not have documented transition agreements for the directed energy programs that GAO reviewed. The Air Force has not consistently prioritized establishing transition partners, which makes planning for future transition even more challenging. Without these transition planning steps, the Navy and Air Force risk developing directed energy weapons that may be misaligned with operational needs.[59]

[58] Rich Abott, "Navy Cautious on Lasers Because First Program of Record Could Cost $1 Billion, ONR Official Says," *Defense Daily*, February 15, 2023.

[59] Government Accountability Office (GAO), *Directed Energy Weapons: DOD Should Focus on Transition Planning*, GAO 23-105868, April 2023, highlights page.

Legislative Activity for FY2025

Summary of Congressional Action on Selected Navy FY2025 Funding Line Items

Table 1 summarizes congressional action on selected Navy FY2025 funding line items related to SSLs. Research and development funding line items are called Program Elements (PEs). Navy research and development funding related to lasers or directed energy occurs in numerous PEs other than those shown in **Table 1**.

Regarding the request for no funding for line 34 for SSL-TM, the Navy's FY2025 budget submission states that SSL-TM deinstallation, final report, program closeout, and hardware disposition began in the second quarter of FY2023 and are scheduled to be completed in the fourth quarter of FY2024.[60]

Regarding the request for no funding for line 73 for ODIN, the Navy's FY2025 budget submission states that eight ODIN units are now operational in the fleet, and that funding for ODIN has been realigned to realigned to the Other Procurement, Navy (OPN) account for procurement of repair parts, and to the Operations and Maintenance, Navy (OMN) account for sustainment support.[61]

Regarding the request for $5.7 million in funding for line 73 for SNLWS, the Navy's FY2025 budget submission states: "The FY25 budget request supports this Research & Development (R&D) asset by accomplishing at-sea testing of HELIOS on DDG 88 [USS Preble], replenishment parts, development of Engineering Change Proposals (ECPs), obsolescence investigations, end-of-life procurements, In Service Engineering Agent (ISEA) onboard tech assists, Casualty Report (CASREP)[62] responses, logistics support, and Software Support Activity (SSA) cyber security and software support."[63]

Regarding the request for $4.1 million in funding for line 73 for HELCAP, the Navy's FY2025 budget submission states: "The FY25 budget request supports close-out documentation, modeling and simulation, and verification activities for the ASCM detect to defeat demonstration. The results from the demonstration will be processed and captured in final reporting for the HELCAP project. Additional activities included in the FY25 budget include appropriate activities for closeout related to the hardware and software developed under HELCAP."[64]

[60] *Department of Defense, Fiscal Year (FY) 2025 Budget Estimates, Navy, Justification Book Volume 2 of 5, Research, Development, Test & Evaluation, Navy, Budget Activity 4*, March 2024, pp. 180, 185, 186 (PDF pages 256, 261, 262 of 1520).

[61] *Department of Defense, Fiscal Year (FY) 2025 Budget Estimates, Navy, Justification Book Volume 2 of 5, Research, Development, Test & Evaluation, Navy, Budget Activity 4*, March 2024, pp. 924, 951, 952 (PDF pages 1000, 1027, 1028 of 1520).

[62] CASREPs are reports of equipment malfunctions that may degrade a ship's readiness.

[63] *Department of Defense, Fiscal Year (FY) 2025 Budget Estimates, Navy, Justification Book Volume 2 of 5, Research, Development, Test & Evaluation, Navy, Budget Activity 4*, March 2024, p. 936 (PDF page 1012 of 1520).

[64] *Department of Defense, Fiscal Year (FY) 2025 Budget Estimates, Navy, Justification Book Volume 2 of 5, Research, Development, Test & Evaluation, Navy, Budget Activity 4*, March 2024, p. 923 (PDF page 999 of 1520).

Regarding the request for no funding for line 73 for directed energy components for high-energy lasers, the Navy's FY2025 budget submission states that the project "on track to complete in FY24."[65]

Table 1. Summary of Congressional Action on Selected Navy FY2025 Funding Line Items

In millions of dollars, rounded to nearest tenth

		Authorization			Appropriation		
	Req.	HASC	SASC	Final	HAC	SAC	Final
Research and development line items (i.e., Program Elements, or PEs)							
SSL-TM							
PE 0603382N, Advanced Combat Systems Technology (Line 34), Project 2480, SSL-TM	0	0	0	0	0[a]	0[b]	
ODIN							
PE 0603925N, Directed Energy and Electric Weapon System (Line 73), Project 9823, Lasers for Navy application, ODIN	0	0	0	0	0	0[c]	
SNLWS Increment 1 (HELIOS)							
PE 0603925N, Directed Energy and Electric Weapon System (Line 73), Project 3402, Surface Navy Laser Weapon System (SNLWS)	5.7	5.7	5.7	5.7	5.7	5.7[c]	
HELCAP							
PE 0603925N, Directed Energy and Electric Weapon System (Line 73), Project 2731, High Energy Laser Counter ASCM Project (HELCAP)	4.1	4.1	4.1	4.1	4.1	4.1[c]	
Directed Energy Components for High Energy Lasers							
PE 0603925N, Directed Energy and Electric Weapon System (Line 73), Project 5898, Directed Energy Components for High Energy Lasers	0	0	0	0	0	0[c]	
Other Procurement, Navy (OPN) line item							
ODIN							
Directed Energy Systems (line 117), for ODIN	3.8	3.8	3.8	3.8	3.8	3.8	
SNLWS Increment 1 (HELIOS)							
Directed Energy Systems (line 117), for HELIOS	0	0	45.0	0	0	0	

Source: Table prepared by CRS based on Navy FY2025 budget submission, committee and conference reports, and explanatory statements on FY2025 National Defense Authorization Act and FY2025 DOD Appropriations Act. Navy research and development funding related to lasers occurs in other PEs as well.

Notes: HASC is House Armed Services Committee; **SASC** is Senate Armed Services Committee; **HAC** is House Appropriations Committee; **SAC** is Senate Appropriations Committee. *

a. For line 34, the HAC report recommended increases of $5.0 million each for "Program increase—Navy data aggregation enterprise" and "Program increase—threat adaptive command and control." (Page 185)

b. For line 34, the SAC report recommended an increase of $9.0 million for "Program increase: Threat adaptive command and control—Minotaur," and an increase of $4.0 million for "Program increase: Universal AI/ML core environment." (Page 213)

c. For line 73, the SAC report recommended an increase of $10.0 million for "Program increase: 100KW directed energy production." (Page 214)

[65] *Department of Defense, Fiscal Year (FY) 2025 Budget Estimates, Navy, Justification Book Volume 2 of 5, Research, Development, Test & Evaluation, Navy, Budget Activity 4,* March 2024, p. 946 (PDF page 1022 of 1520).

FY2025 National Defense Authorization Act (H.R. 8070/S. 4638/H.R. 5009)

House

The House Armed Services Committee, in its report (H.Rept. 118-529 of May 31, 2024) on H.R. 8070, recommended the funding levels shown in the HASC column of **Table 1**.

Senate

The Senate Armed Services Committee, in its report (S.Rept. 118-188 of July 8, 2024) on S. 4638, recommended the funding levels shown in the SASC column of **Table 1**. The recommended increase of $45.0 million for line 117 is for "HELIOS Long Lead Procurement." (Page 450)

S.Rept. 118-188 states:

> **Directed energy protection capability**
>
> The committee remains concerned about the threat posed by low-cost attritable aerial drones, especially the threat that drone swarms pose to our forces. The committee notes that conflicts in Ukraine and the Middle East clearly demonstrate the utility and proliferation of low-cost attritable aerial drone systems and believes that more must be done to protect U.S. servicemembers from that threat. The committee welcomes the resulting increase in focus of the Department of Defense (DOD) on exploring the use of directed energy systems to defeat these threats at a low cost per engagement.
>
> The committee encourages DOD to prioritize rapidly developing and acquiring directed energy systems to defeat large drone swarms and believes that the Department should utilize all available rapid acquisition pathways to develop and acquire directed energy counter drone swarm systems. Furthermore, the committee directs the Secretary of Defense to provide a briefing to the Committees on Armed Services of the Senate and the House of Representatives, not later than February 1, 2025, on all efforts to develop and procure directed energy systems to defeat large numbers of drones in a single engagement. (Page 80)

S.Rept. 118-188 also states (emphasis added):

> **Directed energy weapons and their role in integrated air and missile defense**
>
> On May 8, 2024, the Strategic Forces Subcommittee held its annual budget hearing "To Receive Testimony on the Department of Defense Activities in Review of the Defense Authorization request for Fiscal Year 2025 and the Future Year's Defense Program." The witnesses testified that the invasion of Ukraine by Russia, and the April 14 attack by Iran and its proxies, in which 300 unmanned aerial vehicles, cruise and ballistic missiles were directed against Israel and U.S. target, had changed the landscape of integrated air and missile defense.
>
> The President's budget request for fiscal year 2025 included $28.4 billion for missile defense and related activities, including Over-the-Horizon Radars, Space-Based Missile Warning and Tracking, and a Next Generation Interceptor for the Ground-based Midcourse Defense system. However, within this budget request, the Missile Defense Agency requested just $10.4 billion—a $500.0 million decrease compared to the fiscal year 2024 enacted budget total. This overall decrease affects three critical **areas where the committee believes the Department of Defense (DOD) should be making greater efforts**: the development of capabilities to intercept and defeat hypersonic missiles; **fielding operationally relevant directed energy systems**; and the use of highly capable

> missile defense interceptors to destroy relatively inexpensive unmanned aerial system threats.
>
> In addition, the President's budget request for the only program in the Department focused on defeating a hypersonic missile during its glide phase, the Glide Phase Interceptor, decreased from $209.0 million in fiscal year 2024 to $182.0 million in fiscal year 2025—a $27.0 million reduction in funding at a time when hypersonic missile threats are growing rapidly. In an attempt to optimize these relatively limited resources for such a difficult, high-risk endeavor, the Missile Defense Agency will down-select to one vendor—rather than adhering to the Government Accountability Office best practice of maintaining two vendors through the initial test phases of the interceptor. Acknowledging this decrease in funding, the Office of the Secretary of Defense witness acknowledged that U.S. hypersonic defenses are inadequate and that DOD needed to focus on hypersonic defenses.
>
> **The committee is also concerned that DOD is using multi-million-dollar missile defense interceptors against $20,000 UAVs, rather than investing in directed energy systems whose cost per shot has the potential to be essentially de-minimis. Missile interceptor costs range from $10.0 million for an SM–3 Block IB missile to $22.0 million for an SM–3 Block IIA missile. At the same time, the budget for directed energy—where the cost of each shot could be a few dollars—has decreased from $1.65 billion in fiscal year 2023 to $789.0 million for fiscal year 2025.** The Department also chose the fiscal year 2025 request to eliminate funding for production of the less-costly SM–3 Block IB, while holding production for the more expensive SM–3 Block IIA at the minimum sustaining rate of 12 per year.
>
> The Department is making progress in many missile defense areas, such as the development of proliferated space sensors for tracking, the AEGIS weapon system, and the SM–3 Block IIA missile for ballistic missile defense. However, the committee recognizes that DOD must take steps to expand its missile defense capacity, as well as its baseline capability, to adequately address rapidly proliferating traditional and asymmetric missile threats. **The committee strongly encourages DOD to pursue much more robust future budgets for** the Glide Phase Interceptor and **directed energy programs**, as well as to reconsider ill-advised decisions to cut existing, combat-proven missile defense capabilities like the SM–3 Block IB missile, when the need for such assets is clearly growing. (Pages 319-320)

Final

The joint explanatory statement for the House-Senate agreement on H.R. 5009 that was released on December 7, 2024, recommended the funding levels shown in the authorization final column of **Table 1**.

FY2025 DOD Appropriations Act (H.R. 8774/S. 4921)

House

The House Appropriations Committee, in its report (H.Rept. 118-557 of June 17, 2024) on H.R. 8774, recommended the funding levels shown in the HAC column of **Table 1**. For line 34, H.Rept. 118-557 recommended increases of $5.0 million each for "Program increase—Navy data aggregation enterprise" and "Program increase—threat adaptive command and control." (Page 185)

Senate

The Senate Appropriations Committee, in its report (S.Rept. 118-204 of August 1, 2024) on S. 4921, recommended the funding levels shown in the SAC column of **Table 1**.

For line 34, S.Rept. 118-204 recommended an increase of $9.0 million for "Program increase: Threat adaptive command and control—Minotaur," and an increase of $4.0 million for "Program increase: Universal AI/ML core environment." (Page 213)

For line 73, S.Rept. 118-204 recommended an increase of $10.0 million for "Program increase: 100KW directed energy production." (Page 214)

Appendix. Potential Advantages, Limitations, Costs, and Cost-Effectiveness of Shipboard Lasers

This appendix presents additional information on potential advantages and limitations of shipboard lasers.

Potential Advantages

In addition to a low marginal cost per shot and deep magazine, potential advantages of shipboard lasers include the following:

- **Fast engagement times.** Light from a laser beam can reach a target almost instantly (eliminating the need to calculate an intercept course, as there is with interceptor missiles) and, by remaining focused on a particular spot on the target, cause disabling damage to the target within seconds. After disabling one target, a laser can be redirected in several seconds to another target.
- **Ability to counter radically maneuvering missiles.** Lasers can follow and maintain their beam on radically maneuvering missiles that might stress the maneuvering capabilities of Navy SAMs.
- **Precision engagements.** Lasers are precision-engagement weapons—the light spot from a laser, which might be several inches in diameter, affects what it hits, while generally not affecting (at least not directly) separate nearby objects.
- **Graduated responses.** Lasers can perform functions other than destroying targets, including detecting and monitoring targets and producing nonlethal effects, including reversible jamming of electro-optic (EO) sensors. Lasers offer the potential for graduated responses that range from warning targets to reversibly jamming their systems, to causing limited but not disabling damage (as a further warning), and then finally causing disabling damage.

Potential Limitations

Potential limitations of shipboard lasers include the following:

- **Line of sight.** Since laser light tends to fly through the atmosphere on an essentially straight path, shipboard lasers would be limited to line-of-sight engagements, and consequently could not counter over-the-horizon targets or targets that are obscured by intervening objects. This limits in particular potential engagement ranges against small boats, which can be obscured by higher waves, or low-flying targets. Even so, lasers can rapidly reacquire boats obscured by periodic swells.
- **Atmospheric absorption, scattering, and turbulence.** Substances in the atmosphere—particularly water vapor, but also things such as sand, dust, salt particles, smoke, and other air pollution—absorb and scatter light from a shipboard laser, and atmospheric turbulence can defocus a laser beam. These effects can reduce the effective range of a laser. Absorption by water vapor is a particular consideration for shipboard lasers because marine environments feature substantial amounts of water vapor in the air. There are certain wavelengths of light (i.e., "sweet spots" in the electromagnetic spectrum) where atmospheric absorption by water vapor is markedly reduced. Lasers can be

designed to emit light at or near those sweet spots, so as to maximize their potential effectiveness. Absorption generally grows with distance to target, making it in general less of a potential problem for short-range operations than for longer-range operations. Adaptive optics, which make rapid, fine adjustments to a laser beam on a continuous basis in response to observed turbulence, can counteract the effects of atmospheric turbulence. Even so, lasers might not work well, or at all, in rain or fog, preventing lasers from being an all-weather solution.

- **Thermal blooming.** A laser that continues firing in the same exact direction for a certain amount of time can heat up the air it is passing through, which in turn can defocus the laser beam, reducing its ability to disable the intended target. This effect, called thermal blooming, can make lasers less effective for countering targets that are coming straight at the ship, on a constant bearing (i.e., "down-the-throat" shots). Other surface ship self-defense systems, such as interceptor missiles or a CIWS, might be more suitable for countering such targets. Most tests of laser systems have been against crossing targets rather than "down-the-throat" shots. In general, thermal blooming becomes more of a concern as the power of the laser beam increases.
- **Saturation attacks.** Since a laser can attack only one target at a time, requires several seconds to disable it, and several more seconds to be redirected to the next target, a laser can disable only so many targets within a given period of time. This places an upper limit on the ability of an individual laser to deal with saturation attacks—attacks by multiple weapons that approach the ship simultaneously or within a few seconds of one another. This limitation can be mitigated by installing more than one laser on the ship, similar to how the Navy installs multiple CIWS systems on certain ships.
- **Hardened targets and countermeasures.** Less-powerful lasers—that is, lasers with beam powers measured in kilowatts (kW) rather than megawatts (MW)—can have less effectiveness against targets that incorporate shielding, ablative material, or highly reflective surfaces, or that rotate rapidly (so that the laser spot does not remain continuously on a single location on the target's surface) or tumble. Small boats (or other units) could employ smoke or other obscurants to reduce their susceptibility to laser attack.[66] Measures such as these, however, can increase the cost and/or weight of a weapon, and obscurants could make it more difficult for small boat operators to see what is around them, reducing their ability to use their boats effectively.
- **Risk of collateral damage to aircraft, satellites, and human eyesight.** Since light from an upward-pointing laser that does not hit the target would continue flying upward in a straight line, it could pose a risk of causing unwanted collateral damage to aircraft and satellites. The light emitted by SSLs being developed by the Navy is of a frequency that can cause permanent damage to human eyesight, including blinding. Blinding can occur at ranges much greater than ranges for damaging targeted objects. Scattering of laser light off the target or off fog or particulates in the air can pose a risk to exposed eyes.[67]

[66] See, for example, Kelsey D. Atherton, "China Plans to Defeat American Lasers with Smoke," *Popular Science*, May 3, 2016.

[67] The United States in 1995 ratified the 1980 Convention on Prohibitions or Restriction on the Use of Certain Conventional Weapons Which May be Deemed to be Excessively Injurious or to Have Indiscriminate Effects. An (continued...)

Potential Costs and Cost-Effectiveness Compared with Other Systems

An October 2021 Navy information paper on the potential unit procurement costs of shipboard lasers and their potential cost-effectiveness relative to other Navy shipboard weapon systems states

> The Navy anticipates that laser weapon systems will augment other weapons (kinetic and non-kinetic), sensors, and the overall combat system in complex ways that do not facilitate direct allocation of a specific "combat value" to the contribution of each individual platform. Furthermore, adding to the complexity is the multi-mission nature of laser weapon systems, the evolution of advanced threats, the doctrinal approach the Navy takes in the near-peer fight, and uncertainties in projecting the acquisition and total life-cycle costs of laser weapon systems in future production. However, the Navy recognizes that it must refine the understanding of laser costs and establish measures for contribution to the defense of the Fleet in order to support programmatic decisions. With this in mind, the explanation below outlines the current assessment of relative weapon system costs and associated caveats, along with a path forward for determination of a meaningful measure of combat value.
>
> The Navy has been working to develop cost estimates for procurement of future laser weapon systems in order to support Navy programmatic considerations. The fidelity of cost analysis for future laser weapons is limited by the following factors:
>
> — There are no previous programs of record for shipboard laser weapon systems in the Department of Defense from which to draw historical comparisons, particularly in the area of logistics and life-cycle cost.
>
> — Technologies for laser weapons beyond the current state-of-the-art are still in development with S&T [science and technology] and BA-4 [Budget Activity 4] R&D [research and development] funding.
>
> — Besides the Navy contract with Lockheed Martin for the Mk 5 Mod 0 HELIOS, there are no other current major procurement contracts that can be used to benchmark cost models for moderate to high rates of production.
>
> — The industrial base for major sub-systems and components for laser weapon systems is not yet mature when it comes to production capacity.
>
> Given the above caveats and based on current HELIOS data, the Navy estimates the per-unit cost of a 60 kW class laser with relatively mature beam control and combat system integration at moderate production rates will be approximately $100M [million] in limited quantities. For weapons at greater power and/or beam control complexity, the estimates range up to $200M/unit for lasers in the 250 kW class (inclusive of laser, beam director, beam control, power and thermal management, combat system integration, and installation) but with significant uncertainty bounds based on numerous assumptions.

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international review of the convention began in 1994 and concluded in May 1996 with the adoption of, among other things, a new Protocol IV on blinding laser weapons. The protocol prohibits the employment of lasers that are specifically designed to cause permanent blindness to the naked eye or to the eye with corrective eyesight devices. The United States ratified Protocol IV on December 23, 2008, and it entered into force for the United States on July 21, 2009. DOD views the protocol as fully consistent with DOD policy. DOD believes the lasers discussed in this report are consistent with DOD policy of prohibiting the use of lasers specifically designed to cause permanent blindness to the naked eye or to the eye with corrective eyesight devices. For further discussion, see Appendix I ("Protocol on Blinding Lasers") in CRS Report R41526, *Navy Shipboard Lasers for Surface, Air, and Missile Defense: Background and Issues for Congress*, by Ronald O'Rourke.

> From a procurement cost perspective, kinetic and non-kinetic weapon system costs are relatively comparable to those of laser systems, ranging from $70M to $150M, with installation costs that vary, depending on whether they are [for] new construction [ships] or back fit [onto existing ships]. After procurement, the costs for engagements by laser weapons are substantially lower than any comparable kinetic system, with estimates ranging from single dollars ($1.15 – 60 kW) to at most several 10's of dollars per shot (estimated $9.20 for 480 kW).
>
> As the Navy continues to mature Laser Weapon Systems and analyze their integration into the overall combat system, the cost per kill metrics will be refined to specify adequate return on investment. Given the current uncertainty in relative contributions of the various systems being evaluated and the sensitivity to doctrinal implementation and logistic assumptions, it is too early to assign a meaningful value that can be attributed purely to the implementation of laser weapon systems.[68]

Earlier CRS Report

For additional background information on potential Navy shipboard SSLs, see CRS Report R41526, *Navy Shipboard Lasers for Surface, Air, and Missile Defense: Background and Issues for Congress*, by Ronald O'Rourke.

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Disclaimer

[68] Source: Navy information paper on shipboard lasers dated October 20, 2021, provided to CRS by Navy Office of Legislative Affairs on November 17, 2021.