DDG FLT IIA Laser Retrofit

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The US Navy been investing great resources into modernizing the fleet with advanced technologies that can keep maintain maritime superiority over its peer and near-peer competitors. Specific interest has evolved within the electromagnetic spectrum and the development of laser weapons systems. The first solid-state laser (SSL) weapon installed on a ship was the 30 kW beam power Laser Weapon System (LaWS) onboard the USS Ponce from 2014 to 2017. Other SSL weapons have been implemented but have focused their ability on small boats and UAVs. As laser technology has improved, their ability to combat different threats has come to fruition. Specifically, the US Navy is looking to integrate a 300 kW Laser Weapons System (LWS) onboard a FLT IIA DDG to combat Anti-Ship Cruise Missiles (ASCMs). This conversion project explored the feasibility of integrating a 300 kW LWS, to include its power requirements and auxiliary support systems. The focus of the conversion was identifying the Space, Weight, Power, and Cooling (SWAP-C) in order to validate if the LWS could fit into the existing structure and be supported by currently installed power and cooling capabilities. Both structural integrity and ship stability were verified once the identified sizes and weights were known.

A300 kW LWS carries a relatively low efficiency of 25-30%. For this study, efficiency was assumed to be 25% to account for "worst-case" scenario. Other assumptions that played a role in this conversion were that the LWS would replace the aft Close-In Weapons System (CIWS) and its associated spaces, 01 level aft habitability spaces were consumable for the LWS, and a laser pulse (lase) would last six seconds. The 300 kW LWS was treated as a "black box" with global requirements provided by the project's sponsors. The three major subsystems marked for study were the power management system, thermal management system, and dry air supply system. The interaction between those subsystems and the LWS are shown in Figure 1.

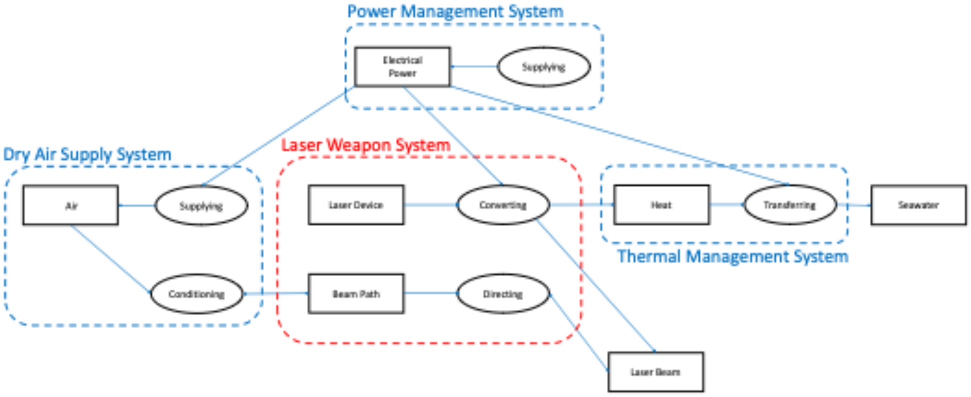


Figure 1. LWS System Decomposition

To support 300 kW of "lase" power, it was determined that a battery-based power supply of 200 kWh of energy and 222 Ah of capacity was needed. These values include a 35% margin to account for uncertainty and inefficiencies. The next factor to consider was battery chemistry. Lithium-ion, (*Li-ion*) Lithium-Iron Phosphate ($LiFePO_4$), and Nickel-Zinc (*NiZn*). Although Li-ion presented the most efficient energy storage system, its fire safety risks would create a great damage control related challenge onboard a warship. This study would ultimately recommend NiZn for risk reduction, given that there is adequate space and weight allowance within the DDG.

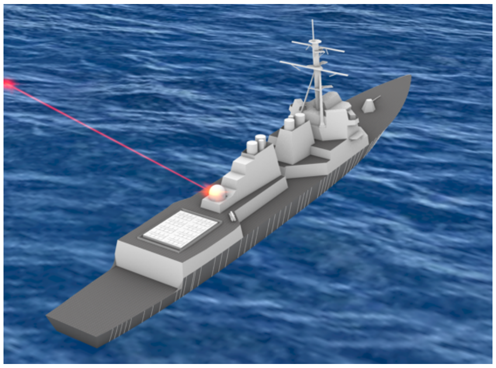
To meet the meet the challenge of cooling the LWS, three different systems were analyzed: Chill Water with Thermal Storage Module (CW with TSM), Pumped Refrigerant, and High Temp LWS (HTLWS). In each case the cooling system would have to reject 900 kW of heat flow (256 RT) rapidly to maintain temperature in the LWS. Although further ship impact analysis focused on the weight/space impacts of the CW with TSM system, this study would recommend the HTLWS based on having the least amount of additional equipment needed and would also provide for future combat systems install due minimal demand from the CW system.

In order to maintain controlled flow within the beam path, the LWS required a dedicated, oil-free Dry Air Supply system. The Dry Air Supply system was design to be within Collective Protection System (CPS) boundaries to minimize contamination and control air quality. The system was size and weight estimates were drawn from commercial sourced equipment to be accounted for in revised ship structural and stability calculations.

Shipboard impacts were also investigated during this study. Spatial arrangements were estimated based on equipment sizing and ships drawings. Weight estimates were conducted and used in determining ship stability impacts. With the additional loading, a structural analysis was conducted utilizing beam theory to determine new stresses. U.S. Navy shipboard electrical plant sizing requirements were then verified based on LWS power demands. Finally, shipboard auxiliary systems were discussed to account for second and third order effects of a LWS conversion. Relevant parameters are presented in Table 1.

Table 1. Summary of Relevant Ship Characteristics

	Baseline	Conversion (LWS)	Change (%)
Displacement (LT)	9256	9299	0.46%
KG (ft)	24.85	25.02	0.68%
GM (ft)	3.46	3.34	-3.47%
Stress_{keel} (ksi)	16.27	16.72	2.80%
Stress_{deck} (ksi)	16.43	16.89	2.81%



This study validated the feasibility of installing a 300 kW LWS onboard a FLT IIA DDG and would recommend the U.S. Navy pursue this system. It is also recommended that the Navy choose proven or near-proven systems to support a short turnaround for a DDG conversion, testing, and fleet integration. Future studies should look to investigate the impact of scaling a LWS based on power to determine feasibility as a conversion opportunity or identify the need for larger LWS integration into new construction.