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Green Ships Bringing the Green Machine to the Fight: How a New Concept Small Deck Amphibious Ship Can Enhance the US Navy Energy Security Posture

ABSTRACT

Energy security and fossil fuel independence remain a dominant strategic imperative two years after the Secretary of the Navy; Honorable Ray Mabus defined a vision for the US Navy's Energy posture. The necessity of fossil fuels exposes vulnerabilities in our ability to perform the dynamic US Navy amphibious mission following a drawdown of sustained high intensity conflict in Iraq and Afghanistan. The need to address these vulnerabilities drives the development of innovative solutions to properly outfit ships with the technology and tools required to meet the fluid challenges of operating a forward deployed Navy. The current amphibious Fleet will be outfitted with energy efficiency enabling technologies over the next several years but as it ages into obsolescence over the following 30 years, new ships will need to be continuously designed and built with energy as a Key Performance Parameter (KPP) to ensure our future fleet maintains a strong Energy Posture. The Navy's engineering community will begin an Analysis of Alternatives in 2012 for the next Dock Landing Ship LSD(X). This provides the Navy a prime and unparalleled opportunity to design and specify a ship that meets the Amphibious Assault needs set forth by the Combined Navy and Marine Corp amphibious assault strategy while saving fuel enhancing operations ashore and efficiently and effectively bringing Marines to the fight.

INTRODUCTION

Reducing surface ship energy consumption while maintaining combat capability can be achieved with a smart and deliberate ship design that utilizes the lessons learned from the LSD41/49 (Whidbey Island Class) and the LPD17 (San Antonio Class) while leveraging ongoing efforts by the Navy's Maritime Energy community. With a design that selects energy efficient system architectures based on expected operational profiles and incorporates developing and proven Energy Conservation Measures (ECM) prior to the LSD(X) procurement in 2017, the design focus can be set on reducing the propulsion requirement, reducing combat system and hotel loads, efficiently removing heat from the ship, and encouraging the use of the tools that will enable the sailor to make smarter energy decisions. In addition, this effort will also enhance and propagate a demand signal for future Research and Development programs that can be back fit into the amphibious warfare ships after Fleet introduction as well as be leveraged by other shipbuilding programs.

By analyzing current LSD(X) requirements, fully understanding the intended operational profile, and leveraging lessons learned from the LSD41/49 and LPD17 classes, future designs will meet defined capabilities while reducing the total ownership cost associated with the rising and unstable cost of fuel. By developing smart systems engineering solutions that leverage low risk technologies, the LSD(X) is an ideal candidate for simultaneously incorporating Energy as a KPP and driving the amphibious Fleet to continue to lower fuel consumption after the in-service Fleet has met and surpassed the 2020 SECNAV and CNO Energy Goals (Navy Energy Vision 2010).

The opportunity to influence a new ship design in the early stages rarely presents itself. The new LSD(X) concept design has the ability to set the tone in new ship designs and provide the Navy with a lethal and effective fighting capability

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while also reducing the energy requirement to sail the Next Navy and the Navy after Next.

SYSTEMS ARCHITECTURE

Historically, propulsion plants have been sized to be efficient at maximum and endurance speeds, typically 22+ knots and 20 knots for a small amphibious assault ship. Operationally these ships spend a majority of their time between 5 and 15 knots, leaving a mismatch between design efficiency and actual operation. As the Navy looks forward to include energy requirements in acquisition programs, possibly in the form of a Key Performance Parameter (KPP), it needs to ensure that this requirement informs the design based on a realistic mission profile. This will ensure the hull, propeller, and machinery plant is designed to be most efficient at those speeds and readiness conditions that will likely dominate the ship's operational profile.

One method to ensure a holistic energy approach to the design would be to allocate energy budgets to the various ship systems/components using either the Ship Work Breakdown Structure or a decomposition of the ship functions. This energy budget would be developed from an overall energy baseline. Ongoing class energy baselining efforts via Energy Surveys for LSD-41/49 class can be leveraged to establish the overall energy baseline for the new design. This is similar to the budgeting efforts used during ship design for cross-functional items including weight and manning.

ALTERNATE PROPULSION AND POWER ARCHITECHTURES

Alternate propulsion and power architectures that will offer the most realistic options for implementation are Hybrid Mechanical-Electric systems similar to the USS Makin Island (LHD 8) Auxiliary Propulsion System (APS), the DDG51 Hybrid Electric Drive (HED) Program, or the auxiliary Keyser Class (TAO-187). Another realistic opportunity for an alternate propulsion concept would be an Integrated Power System (IPS) similar to the architecture utilized on the DDG1000 or the TAGS-66 military survey ship. All alternate propulsion concepts may offer space savings through the increased energy density provided by modern power electronics as well as the potential reduced "losses" in the electrical system. (Martin, McCoy, Doerry)

In the case of APS and HED, an in depth study would need to be conducted to ensure that the benefit of the insertion of a hybrid propulsion plant would be properly sized to perform a majority of the intended mission, especially transit, and yield benefits beyond maintenance savings of properly loading the diesel engines.

HULL VARIANTS

Energy Conservation Measure (ECM) insertion may apply to select hull variations considered for the LSD(X) or may be capable of integrating with any variant selected depending on space and weight reservations as well as propulsion concept maturity (Diesel, Steam, Gas Turbine, or Nuclear). The three most likely options for a hull type are LSD41/49 restart/variant, LPD17 variant, or an outright new hull design. All three options possess pros and cons dependent on the combat requirements set by amphibious force needs; however controlling costs throughout the lifecycle of LSD(X) can be achieved by the careful insertion of ECMs early in the acquisition lifecycle. According to a high level review of Navy Energy Utilization Report System (NEURS) data from 2008-2010, the LSD41/49 class averages for Underway Fuel Consumption were lower than the LPD17 class. However, there are different capabilities between both classes including LCAC spaces, Helicopter Spaces, Troop capacity, and cargo volume that need to be defined by the joint defense strategies.

There is an opportunity in the development of an LSD(X) concept to reduce the underway fuel consumption utilizing a LPD17 class variant with ECMs installed which would bring a larger ship with arguably more capability to LSD(X) and operate at a lower fuel consumption than either the LSD41/49 and LPD17 classes. This would make for an ideal design point, but all the factors of varying technology insertion options need to be evaluated in depth.

Restarting the LSD41/49 class could be using a tried and true opportunity to restart a known production line while updating the ship with ECMs that would further strengthen the class's impact on the surface fleet's energy posture.

An outright redesign of a unique hull may be costly, take longer, and introduce risk and a steep learning curve similar to the lessons learned as part of rolling out the LPD17 class. However, a clean sheet approach may best supply the LSD(X) concept with a truly energy efficient hull form that would drastically reduce the propulsion requirement for the ship.

The most important factor in choosing a hull type in this fiscally constrained environment is an achievable design that leverages the lessons learned in the systems engineering process by the Navy as well as the manufacturing lessons learned by the Navy's shipbuilding partners.

HYDRODYNAMIC IMPROVEMENTS AND MODFICIATIONS

The selection of the hull may be the most critical component when designing a future amphibious ship that utilizes less energy than the existing Fleet. A US Navy surface ship utilizes most of its fuel underway, and of that energy consumption, the majority of that energy is dedicated to driving a ship through the water. In this process there are several losses in the mechanical and electrical processes that contribute to propulsion power, highlighting an easy target for the reduction of propulsion requirement.

LSD41/49 VARIANT AND LPD17 VARIANTS

In order to reduce the propulsion requirement on an LSD(X) that utilizes a prior design, modifications to the existing hull need to be studied in depth by the Navy's Surface Warfare Directorate Carderock Division (NSWCD) as well as pointed independent studies by some of the world's leading naval architects. The designs of the existing ships reflect the previous requirements of cargo volumes, troop capacity, and vehicle storage, but utilizing some mature but unrefined concepts for the LSD(X) may contribute substantially to energy reduction.

MODIFIED STERN FLAP

Stern flaps are currently being back-fitted into the LSD-41/49 class. In order to ensure that a stern flap is most effective on LSD(X) and achieves maximum efficiency while not causing detrimental losses at the high end of the operating profile, a substantial survey should be made of the existing Amphibious Fleet operating profile in order to determine which speed the LSD(X) will spend most of its operation time. This may also be achieved with an adjustable stern flap that can be trimmed for the entire speed range of the LSD(X).

FRICTION DRAG REDUCTION

An additional initiative which has been evaluated at the David Taylor Model Basin at NSWCCD is the concept of releasing air bubbles along the hull of a ship. This modification functions by inducing turbulence along the hull and disturbing the boundary layer which causes drag and additional power required to push the ship through the water. This initiative may not work on the drastic hull curves of a modern surface combatant but may be optimal for the flatter and more box like hull forms of the LSD41/49 and LPD17.

NEW HULL FORM

The benefit of utilizing a new hull form is that the entire design may incorporate a hull form that includes the appropriate combat capability, the required signature characteristics, and lower propulsion requirement. It is likely that a new hull form that has a lower propulsion requirement while meeting combat requirements can drastically limit the Amphibious Fleet's energy consumption. It needs to be noted that the effort of designing a new ship from the keel up may incur the cost and timeline of a new ship design while also losing the lessons learned working through the engineering challenges of continuing or modifying an existing design.

NEW PROPELLER

A new controllable pitch propeller (CPP) design taking advantage of new blade designs and smaller propeller hubs could yield significant energy savings to any of the proposed variants. A fully integrated or hybrid electric propulsion and power system would allowed the use of a fixed pitch propeller (FPP) design and could result in a 5-10% efficiency gain over a CPP at full power.

Any new propeller design needs to fully consider the operational profile of the ship. If it is intended to pair a FPP with a hybrid motor, that motor will need to be sized to execute astern and crash maneuvers. A CPP, while less efficient at full power, can be controlled at lower speeds to improved overall efficiency.

MECHANICAL ECMs

Mechanical initiatives span several disciplines in ship construction from defining the propulsion architecture or increasing the efficiencies of fluid systems. However, in a design of LSD(X) multiple modifications apply to either the existing designs or a new hull design (unless exact product line restarts are initiated of LSD41/49 and LPD17).

IMPROVED DIESEL ENGINES AND OPTIMAL DIESEL ENGINE ARCHTITECTURE

The LSD(X) does not necessarily require a different diesel engine manufacturer as a deviation from LSD41/49 or LPD17 classes, but can take advantage of modifications and updates included in commercial diesel engines as well as ECMs currently under development. These modifications include common rail, “smart” controls and sensors, the ability to run off of alternate or multiple fuel sources, and proper father-son configuration of engine sizes.

Adding these features into a diesel engine will increase fuel consumption characteristics of LSD(X). As previously noted the LPD17 class of ship utilizes less fuel per underway hour than the LSD41/49 class despite the greater vessel displacement and crew size. Gains in the energy profile will make a noticeable budgetary impact and provide the means to properly load the engines across the speed range, which is critical to avoid potential maintenance issues. This can be done by providing several properly sized diesel engines to ensure that the engines are optimally loaded over the speed range of the ship. If larger engines are under loaded for prolonged periods, maintenance issues arise as well as increased wasted fuel and poor combustion.

ELECTRIC REQUIREMENT REDUCTION ECMS

The final category of energy savings through technological means comes in the form of reducing the electrical loads or increasing the efficiency of transmitting power through the ships electrical distribution system. In conjunction with concept of energy budgeting by SWBS group, serious consideration should be given to incorporate minimum energy efficiency rating for various components to include pumps and motors into the ship specification. Similar to sizing the propulsion and power plants, these efficiency requirements need to consider the overall operating profile of the ship to ensure efficient operation at part loads as required by the ship’s mission.

Current ECMs in development or use in the commercial world include Variable Speed Drives (VSDs), Alternate Voltage ratings for distributions systems, and Higher Efficiency HVAC and Refrigeration systems.

VARIABLE SPEED DRIVES (VSDs)

VSDs have multiple applications on US Navy Vessels and are starting to be recognized as a viable candidate for insertion Fleet wide. VSDs provide ships with the ability to adjust the capacity of the attached system reducing load in times of low use and increasing the capacity when the system requires. In a recent Shipbuilder Special Study for DDG111, it was cited that the utilization of a variable motor for the central seawater cooling pumps will save tens of thousands of dollars and have a return on investment within a few years. A ship wide utilization of VSDs designed into the ship where applicable stands to save millions of dollars throughout the lifecycle of the ship.

FIREMAIN

VSDs are an excellent choice for implementation in the Ship's firemain system because it is required to be ready for use at all times, but the system does benefit from maintaining system pressure with continuously running and maintaining a relatively high power requirement. Another option being employed on DDG-1000 is to charge the firemain with freshwater. A freshwater charged firemain system requires a small circulating pump to prevent fouling which significantly reduces energy consumption over existing seawater systems.

HIGH EFFICIENCY HVAC AND REFRIGERATION

Utilizing VSDs, magnetic bearings, and a high performance permanent magnetic motor in HVAC and Reefer systems provide measurable and mature options for reducing the auxiliary loads on LSD(X). It will also enhance the combat capability of the LSD(X) by providing a cooling margin and managing energy costs through the lifecycle of the ship. Tie these cooling units into a smart ventilation system that allows controlled and dynamic cooling to the entire ship's spaces and the technology presents itself as a major candidate for insertion in the LSD(X) class. (Naval Energy Forum, 2009)

The High Efficiency Small - Capacity (HES-C) Chiller currently under development by NAVSEA was kick started using American Recovery and Reinvestment Act (ARRA) funds. The R134a two-stage, oil-free, variable speed compressor is designed to be as much as 40% more efficient with 50% more cooling capacity using the same shell as existing DDG-83AF units. The HES-C compressor is being evaluated for use on the DDG-51 Flight III and Ohio Replacement programs as well as the potential opportunity for backfit on the DDG 83AF and LPD 17.

SOLID STATE LIGHTS

Solid state lights (SSL) are a smaller energy saver as the lighting loads on surface ships tend to be a lower cost driver compared to propulsion, power generation, and mission loads. However, it is still an opportunity to reduce energy by designing in the proper fixtures and bulbs that will provide a lower maintenance cost as well as energy reduction. SSLs are already in demonstration in some Fleet assets and as the Navy starts to issue contracts for backfit in 2012, the maturity and access to multiple vendors will increase to a favorable level for implementation in LSD(X)

THERMAL DESIGN AND ANALYSIS

With the increasing energy demands of combats systems and increase use of solid state equipment, the efficient removal of heat from the ship is becoming a high priority. A comprehensive thermal analysis of the ship will enable the design of an efficient holistic approach. Things to be considered during the thermal design includes topside coatings to reduce HVAC loads, heat pumps, hot or cold energy storage capabilities, and waste recovery systems that will take advantage of excess energy otherwise wasted. A properly designed ship from a thermal efficient perspective may not have enough energy to easily recover but it is important to understand the current Amphibious ship's energy waste areas to avoid these pitfalls in any future design or address if modified version of the LSD41/49 or LPD1& hulls are revisited for LSD(X).

TOPSIDE COATINGS

Topside coatings that reduce the absorption of heat from the sun and extreme temperatures that US Navy ships tend to operate. In the higher temperature range Low Solar Absorption (LSA) coatings are under investigation and development as a way to reduce the Heating Ventilation and Air Conditioning (HVAC) loads on ships that have a primary mission of berthing and transporting marines. By reducing the external thermal loads on the ship the HVAC plants can be optimized; therefore, driving down the electrical loads on the ship.

HEAT PUMPS

WASTE RECOVERY

CONCLUSION

The design, construction, and introduction of LSD(X) into the amphibious ship inventory provide the Navy with an unparalleled opportunity to act on the SECNAV and CNO Energy Goals in a new acquisition and construction program for the Surface Fleet. A holistic systems architecture approach is of utmost importance as combat system capabilities increase and compete equally with mobility for energy. A representative operating profile that not only defines the time at various ship speeds, but also defines the ship's mission posture at those speeds is the basis for making sound, long lasting decisions.

By implementing the majority of the technologies noted in this paper, the energy posture of the surface Fleet will greatly be enhanced along with the combat capability and industrial base expansion. In the years following the Alternative of Analysis for the LSD(X), Government and Industry partners alike will see the investment in new and innovative Energy Conservation Measures as a demand signal to continue to search out and develop mature, low risk, and energy efficiency enabling technologies for implementation into the fleet. By reducing the cost of energy to transport Navy fighting forces, the Navy will deny aggressive foreign entities our petro dollars and expand the US Marine Corp's reach and mission to meet their strategic requirements. Energy must be included as a major pillar of the LSD(X) design; as its not only a component of reduced total ownership cost, it is a major aspect of increasing our tactical reach and flexibility in the dynamic world of modern naval and expeditionary combat.

REFERENCES

Navy Energy Forum, Maritime Energy Technology Fact Sheets, October 2009

Navy Energy Vision, October 2010

Martin, Doerry, McCoy, "Energy and the Future Affordable Fleet", INEC, May 2010

Biographies

Tom Martin is presently the Director of the Energy Office within the NAVSEA 05 Chief Technology Office (SEA 05T). He is assigned as NAVSEA's representative to Task Force Energy, is a member of the Navy Energy Coordination Office, and is the co-lead of for the Maritime Energy Working Group. Mr. Martin holds a Bachelors of Science in Physics from Ithaca College and Mechanical Engineering from Rochester Institute of Technology.

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