

NOT FOR PUBLICATION UNTIL RELEASED BY
THE HOUSE ARMED SERVICES COMMITTEE
SUBCOMMITTEE ON PROJECTION FORCES

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BEFORE THE

SUBCOMMITTEE ON PROJECTION FORCES

OF THE

HOUSE ARMED SERVICES COMMITTEE ON

INTEGRATION OF ENERGY EFFICIENT PROPULSION SYSTEMS
FOR FUTURE U.S. NAVY VESSELS

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INTRODUCTION

Mr. Chairman, distinguished members of the Projection Forces Subcommittee, thank you for this opportunity to appear before you to discuss alternative propulsion systems, methods, and techniques to reduce the Navy's dependency on fossil fuels and the Integration of Energy Efficient Propulsion Systems for Future U.S. Navy Vessels.

The Naval Research Advisory Committee (NRAC) provided a brief on Future Fuels to Flag Officers and Senior Executive Service in October of 2005. The NRAC is an independent civilian scientific advisory group dedicated to providing objective analyses in the areas of science, research and development. The NRAC calls attention to important issues and presents Navy management with alternative courses of action. It is the senior scientific advisory group to the Secretary of the Navy, the Chief of Naval Operations, Commandant of the Marine Corps, and the Chief of Naval Research. As a permanent committee of experts, it acts as a corporate consultant and advisor to top-level Navy officials. The NRAC brief indicated that the 2003 national petroleum usage was 16 million barrels a day (bbl/d) with the federal government using 330,000 bbl/d or 2 %. The Department of Defense accounts for 91% of federal usage. Within the Department of Defense only 8 % is used by ships at seas, 15% on ground vehicles and 73% on aircraft. Within the 8% of petroleum used at sea, the Navy remains committed to making the most efficient use of the energy resources allocated to us.

FORCE STRUCTURE

Force structure requirements were developed and validated through detailed joint campaign and mission level analysis, optimized through innovative sourcing initiatives

(Fleet Response Plan (FRP), Sea Swap, forward posturing) that increase platform operational availability, and are balanced with shipbuilding industrial base requirements. This force structure was developed using a capabilities-based approach measured against the anticipated threats for the Fiscal Year 2020 timeframe. The future Navy will remain sea based, with global speed and persistence provided by forward deployed forces, supplemented by rapidly deployable forces through the FRP. To maximize return on investment, the Navy that fights the Long War, The Global War on Terror (GWOT) and executes Maritime Security and Stability Operations will be complementary to the Navy required to fight and win any Major Combat Operation (MCO). This capabilities-based, threat-oriented Navy can be disaggregated and distributed world wide to support Combatant Commander GWOT demands. The resulting distributed and netted force, working in conjunction with our joint and maritime partners, will provide both actionable intelligence through persistent, Maritime Domain Awareness, and the ability to take action when and where a threat is identified. The same force can be rapidly aggregated to provide the strength needed to defeat any potential adversary in an MCO. The warships represented by this shipbuilding plan will sustain operations in forward areas longer, be able to respond more quickly to emerging contingencies, and generate more sorties and simultaneous attacks against greater numbers of multiple targets and with greater effect than our current fleet.

Employing a capabilities-based approach to calculate the size and composition of the future force required to meet expected Joint Force demands in peace and in the most stressing construct of the Defense Planning Guidance, along with detailed assessments of

risk associated with affordability and instabilities in the industrial base, the analysis concluded that a Fleet of about 313 ships is the minimum force necessary to meet all the demands, and to pace the most advanced technological challengers well into the future, with an acceptable level of risk. The Navy continues to analyze operational requirements, ship designs and cost, acquisition plans and tools and industrial base capacity to further refine its shipbuilding plan. Full funding and support for execution of this plan is crucial to transforming the U.S. Navy to a force tuned to the 21st Century and its evolving requirements.

THIRTY - YEAR NAVAL FORCE SIZE

The 30-year shipbuilding plan and the resulting ship inventory, as outlined in the Fiscal Year 2007 Annual Long-Range Plan for Construction of Naval Vessels, represent the baseline as reflected in the 2007 President's Budget submission. There will be subsequent studies and analysis that will continue to balance affordability with capability and industrial base capacity. As part of the Fiscal Year 2008 budget development process, the Navy will be exploring alternative approaches to attaining the future force structure and ship mix while retaining the necessary capabilities for Joint Force operations. Overall, this plan reflects the Navy's commitment to stabilize the demand signal to the industrial base while still achieving the appropriate balance of affordability and capability in all ship Classes. Although there is some limited risk with this plan, and not a lot of excess capacity to accommodate the unforeseen, we believe the risk is moderate and manageable.

SECNAV STUDY OF ALTERNATIVE PROPULSION METHODS

The Naval Sea Systems Command is responsible, on behalf of the Secretary of the Navy, for the technical execution of the analysis of alternative propulsion methods for surface combatant and amphibious warfare ships, required by Section 130 of the Fiscal Year 2006 National Defense Authorization Act. The results of this analysis will be detailed in a report to the congressional defense committees not later than November 1, 2006.

Guided by the Section 130 framework, the Fiscal Year 2006 Alternative Propulsion Study will build upon the methodology and results of a Fiscal Year 2005 study led by the Naval Sea Systems Command. Specifically, the Fiscal Year 2006 study will analyze alternative propulsion systems using both nuclear, fossil fuels, and other forms of energy; model propulsion systems in amphibious warfare ships, medium surface combatants (multi-mission air defense) and small surface combatants (multi-mission sea dominance); evaluate cost versus operational effectiveness; and compare nuclear with diesel fuel marine (DFM) plant alternatives. The Fiscal Year 2006 study will consider technologies such as nuclear power, gas turbines, diesels, fuel cells, mechanical drive, electrical drive, various types of propellers and podded propulsor systems, as well as other innovative concepts. The study will incorporate aspects of these technologies that are anticipated to be mature for transition to ship acquisition programs in the next twenty years.

The FY06 Study will include the following tasks.

1. Development of Study Guides for amphibious warfare ship variants, medium surface combatant ship variants, and small surface combatant variants. These study guides will document the study assumptions, assumed mission systems, boundaries, methods, techniques, tools, and expected products.
2. Energy Needs Determination: Each variant will be analyzed to determine propulsion and electrical power needs for various operating conditions. The assumptions and methods documented in the study guides will guide this effort.
3. Nuclear and Fossil Fuel Propulsion Plant Design Studies: Power plants that meet the Energy Needs determined in (2) will be characterized to the level needed by the Ship Synthesis Model for each propulsion type.
4. Propulsion Plant Architecting and Systems Engineering: For each variant, the basic architecture for and the selection of the type, number, and general location in the ship of prime movers and propulsion equipment will be developed. Each propulsion plant will be evaluated to determine Measures of Performance (MOP) to support follow on cost and effectiveness modeling. The assumptions and methods documented in the study guides as well as feedback from cost and effectiveness modeling will guide this effort.
5. Ship Synthesis: For each variant, a total ship solution that incorporates the propulsion plant characterized in the previous steps as well as the mission systems detailed in the study guides will be synthesized to the conceptual level.

6. Cost Modeling: The conceptual ship design will be analyzed to estimate acquisition cost and lifecycle cost of each variant. For each ship type, a break-even cost analysis will be performed to determine the cost of crude oil for which the life cycle cost of a nuclear propulsion variant of a ship concept will equal the lifecycle cost of a DFM fueled concept. This break-even cost will be presented as a function based on the operational tempo, operational profile, and service life. The life cycle cost estimates incorporate all costs through disposal, including burdened fuel costs, manpower costs, and maintenance.

7. Effectiveness Modeling: To fulfill the study's operational effectiveness analysis requirements, each ship concept will be evaluated in terms of mobility, survivability, and warfare effectiveness. Effectiveness metrics will be measured in the context of operational scenarios and include attributes such as timeliness, percent mission complete, and sustainability.

8. If applicable, the study report will include recommendations and conclusions for incorporating study results into existing and future ships.

In response to guidance from the Chief of Naval Operations in 2005, the Naval Sea Systems Command in partnership with the Naval Surface Warfare Center, Naval Operational Logistics Support Center, Office of Naval Research, Industry, and Academia is conducting a study for alternate propulsion methods for submarines and surface combatants in support of sea basing. This Fiscal Year 2005 study responds to the

question “Will the current propulsion systems meet future navy needs in support of conventional and sea basing concepts of operations (CONOPS) when considering the availability and cost of technology and energy?” The study evaluates the life cycle costs of nuclear and fossil fuel energy sources and mechanical and electric transmissions integrated into surface combatants and submarines. The impact of variations in CONOPS, operating tempo (number of steaming hours per year) and price of fuel on life cycle cost are all analyzed. Although it is premature to discuss the study findings, final review and completion of this study is anticipated around May 2006.

PROPULSION DECISION PROCESS

The Navy evaluates alternative propulsion methods as part of making decisions for naval ship concepts based on a varying number of factors. For submarines, non-nuclear alternatives do not meet our operational requirements. Part 2 of the Analysis of Alternatives (AOA) for what became CVN 78 directly addressed the issue of Nuclear vs. Gas Turbine propulsion for aircraft carriers. This study concluded the military effectiveness provided by nuclear propulsion is well worth the less than ten percent acquisition and life cycle cost premium at that time. At today’s fuel oil prices, this premium is reduced to zero.

For other classes of ships, the calculus is much more complex. Historically, the price of fuel oil has not approached levels that would make reconsideration of nuclear propulsion for surface ships worthwhile on a cost basis alone. A recent analysis indicates that the price of diesel fuel marine would need to approach \$200 per barrel to make nuclear

propulsion acquisition cost neutral over the life cycle of a 15,000 ton destroyer. Nuclear power has not been considered for auxiliary ships.

Other surface ship acquisition strategies rely on modifying an existing design to meet new warfighting requirements. In these cases, the propulsion plant is limited to what fits within the existing design with an attempt to minimize non-recurring costs. Often, the propulsion plant design is replicated with minimal change in the new ship. Using the LHD 8 propulsion plant for LHA 6 is a good example of a modified repeat design employing an existing plant design, which provides savings from reduced fuel consumption, reduced maintenance and reduced crew requirements without any added non-recurring engineering investment for a new propulsion plant.

The CVN 21 propulsion plant will provide significantly increased capability at reduced acquisition and life cycle costs. The CVN 21 propulsion plant will produce 25-percent more reactor energy and three times the electrical generating capacity of a NIMITZ class carrier. These increases will allow for the introduction of new systems such as the Electromagnetic Aircraft Launching System (EMALS), Advanced Arresting Gear and a new integrated warfare system as well as support increased operational flexibility for our aircraft carrier force. Propulsion plant construction costs will be reduced by a million man hours due to simplified system designs resulting in a 50-percent reduction in propulsion plant piping and a 50-percent reduction in major valves and pumps. Reactor department manning will be cut in half, in conjunction with a two-thirds reduction in

propulsion plant watchstanders and a 30-percent reduction in maintenance. The ship is expected to cost \$300M less than a repeat NIMITZ class carrier.

Selection of a propulsion or electrical plant is usually an iterative process. Requirements such as power needed for a given speed requirement certainly are a starting place, but typically the hull form and displacement of a ship evolves and the power requirements associated evolve with it. Equipment weight and power density are also factors, as is cost and technical risk. Lastly, factors such as potential future requirements and risk mitigation for future systems are assessed. For example, the Integrated Power System with electric drive was selected for DD(X) because of its weight, power density, integration with the hull form, reduced signature requirements, and the ability to provide significant additional electrical power to non-propulsion systems as the requirements for the non-propulsion systems evolve.

In sum, the Navy is actively investing in technology that enables affordable, effective, and efficient ship designs. No one type of power system is optimal for all classes of ships. Mission requirements, service life, operational tempo, operational profile, and the assumed cost and availability of fuel all are important factors in determining the best machinery plant for a given ship class.

THE REINTRODUCTION OF ELECTRIC DRIVE INTO MODERN WARSHIPS

Electric drive is not new to the U.S. Navy. Throughout the twentieth century, electric drive has been incorporated in a variety of warships ranging from diesel electric

submarines, to our first aircraft carrier, USS LANGLEY, to a host of destroyers and auxiliary ships. The current battle force includes four diesel electric ocean surveillance ships (T-AGOS). An additional commissioned ship; the research submarine USS DOLPHIN (AGSS 555) employs diesel electric propulsion.

Advances in electric drive technology, the need for improved fuel efficiency over a varied operating profile and the power demands of advanced combat systems increasingly make electric drive and integrated power systems more attractive for surface ships.

ELECTRIC DRIVE PROGRAM DESCRIPTIONS

A number of ships currently in design and construction representing major modernization of surface combatants, amphibious assault ships and fleet auxiliaries are taking advantage of the flexibility and efficiency that an integrated power system offers. T-AKE 1 for example, is using commercial marine electric drive technology. LHD 8, LHA 6 and LHA(R) are all employing a hybrid gas turbine mechanical drive / diesel electric drive plant to gain fuel efficiency when operating at or below 12 knots. DD(X) is integrating an advanced induction motor with a DC zonal distribution system that provides combat systems loads with a substantial improvement in electrical power quality and survivability. For CVN 21, a large increase in electrical generating and distribution capacity was possible without wholesale conversion to the more costly and higher volume and weight option of electric drive. To date, electric drive technology initiatives

have not effectively demonstrated cost, weight or volume reductions when integrated into submarines or aircraft carriers.

T-AKE 1 LEWIS AND CLARK CLASS

The LEWIS and CLARK class is the first ship acquired by the US Navy with an integrated electric and propulsion plant powered by modern AC electric propulsion power. The Integrated Power System (IPS) is an all-electric architecture for the ship, providing electric power to the total ship from an integrated power plant. The IPS enables LEWIS and CLARK's entire electrical load to be powered from the same electrical drive that powers the propulsion systems. This eliminates the need for separate power generating capacities, reduces fuel costs, and lowers the requirements for manning and maintenance, leading to lowered lifecycle costs. Built to commercial ship standards, the basic equipment and design of the T-AKE power plant represents a key advance for Navy Underway Replenishment (UNREP) ships, but is comparable to systems already used in the cruise ship industry and on other existing commercial ships. As such, the IPS offers key benefits without posing the risks often associated with new technologies.

LHD 8 USS MAKIN ISLAND / LHA 6 / LHA(R)

The hybrid electric drive and zonal electrical distribution system that was introduced on LHD 8, USS MAKIN ISLAND, will be the propulsion plant for all of the ships of the Amphibious Assault Ship Replacement Program. Previous large-deck amphibious assault ships (including the LHA 1 Class and LHD 1 through 7) use steam propulsion and steam auxiliary systems. Both LHD 8 and the LHA(R) Program will use the same geared gas

turbine propulsion system for speeds greater than 12 knots and a geared electric drive system for speeds up to 12 knots. A large percentage of an assault ship's operating profile is spent at low speeds and the electric drive system will allow for very efficient operations in that speed regime. By eliminating the steam propulsion plant and steam auxiliary systems of previous amphibious assault ships, the Navy will reduce maintenance costs, increase fuel efficiency and reduce ship manning requirements compared to the LHA 1 Class and LHD 1 though 7.

DD(X)

The DD(X) features an Integrated Power System (IPS) that melds electric drive with a DC zonal electrical distribution system called Integrated Fight Through Power (IFTP). The DD(X) program initially carried two propulsion motor options, Permanent Magnet Motor (PMM) and a fallback Advanced Induction Motor (AIM) and set February 2005 as the appropriate decision point for execution of the fallback option. As part of the risk reduction effort, both PMM and AIM were integrated into the DD(X) Integrated Power System (IPS) Land Based Test Site (LBTS). This test site configuration represents the DD(X) shipboard power system.

The first propulsion-sized PMM experienced failures with its stator insulation system during factory testing in January 2005. Root Cause Failure analysis identified that some implications of scaling the PMM to a much more powerful motor were not fully understood by the manufacturer. Failure of PMM caused the Navy to select the fallback motor, AIM, which had already passed its factory acceptance testing and was ready to

support land based testing. If PMM had met its test schedule and demonstrated the necessary technical maturity there would have been no need to use the fallback motor.

Consequently, the baseline for the DD(X) lead ship was shifted to the fallback AIM system in February 2005 in order to support ship Critical Design Review (CDR). In order to proceed with detail design and construction of DD(X) lead ship(s), the program had to complete land based testing of two Critical Test Parameters (CTP) prior to the conclusion of the ship CDR as directed by Congress in the Fiscal Year 05 Defense Appropriations Act Conference Report (108-622). Two CTPs were successfully tested; one to prove the ability of the propulsion motor to produce torque, and one to verify the Main Gas Turbine fuel consumption to size the ship's fuel load.

While the technology remains an option for insertion in future hulls, PMM represents too much risk for the DD(X) lead ships. While the PMM was not developed in sufficient time to support DD(X) lead ship, the Navy continues to consider it and other innovative propulsion systems candidates for future DD(X) ships and other ship classes once it passes the same rigorous land based testing program that AIM completed. AIM is ready now, is being used on the British Type 45 Destroyer and is a mature technology.

SUBMARINE TECHNOLOGY DEVELOPMENT AND INSERTION

The Navy's submarine technology development efforts focus simultaneously on cost reduction and closure of war-fighting gaps. Advanced Submarine System Development (ASSD) develops and demonstrates the most promising technologies including enablers

for lower submarine acquisition and operation costs. These technologies have applicability to all submarine platforms.

The Navy plans to introduce future major VIRGINIA improvements in successive contract blocks provided they reduce acquisition cost and maintain tactical performance.

The next contract block ship improvement opportunity will be the Fiscal Years 2009 - 2013 authorized ships. A major effort under Advanced Submarine Systems Development is the Joint Navy/DARPA Technology Barrier (Tango Bravo) Program to overcome selected technological barriers and enable design options for a reduced-cost submarine.

SEAWOLF and VIRGINIA Class submarines' nuclear propulsion plant designs include a reactor designed to last the life of the ship. In addition, the VIRGINIA propulsion plant also includes new design features and simplifications to reduce construction and maintenance costs compared to previous submarine classes such as large multi-deck modules, 40 percent fewer pumps, and 25 percent fewer valves, and half as many sea connected components and systems.

For submarines, non-nuclear alternatives do not meet our operational requirements.

TANGO BRAVO SHAFTLESS PROPULSION

The Tango Bravo (Technology Barrier) program is a DARPA and Navy initiative to remove the technology barriers to enable reduced-size and reduced-cost options for future submarines. These same technologies could also enable a submarine of similar size with greatly enhanced payload capacity. The Tango Bravo (Technology Barrier) project is a

technology demonstration and not a submarine design effort. One of the technology areas being explored is shaftless propulsion or propulsion concepts not constrained by a centerline shaft.

The program is focused on a concept that provides for reduced arrangement complexity, which may result in reduced cost. The propulsion technologies to be demonstrated are to be integrated into a high-level ship concept (hull shape with concept-level arrangement of propulsion plant spaces) to support evaluation of the impact of the proposed concepts on overall ship design and cost. The propulsion technology concepts must embody adequate ruggedness, reliability, maintainability and expected lifetime consistent with its intended use as main propulsion for a submarine.

The 48-month effort is constructed in three phases (12/18/18 months respectively) with specified metrics that will serve as decision criteria for continuing to the next phase. The phases generally proceed from detailed design to component build and test and finally to integrating and demonstrating a large-scale model of the propulsion concept. The concept will be tested to determine hydrodynamic performance. Acoustic and electromagnetic signatures will be obtained for the total system and/or individual components. Full-scale signature and hydrodynamic performance predictions will be made using computer models. The effect on overall propulsion plant cost will be calculated to determine if the system meets the goal of shipbuilder cost 60% that of VIRGINIA. This program is sufficiently funded to work in three of five selected technology barrier areas. Three areas, shaftless propulsion, external weapons launch and

electric actuators for stern planes are funded to allow one approach in each area to be developed at scale.

Two contracts were awarded in May 2005 to General Dynamics Electric Boat and DRS Systems, Inc. The two contracts are nearing the end of Phase I. Meaningful demonstration results will be available in Fiscal Year 2008 with final evaluations complete in Fiscal Year 2009.

RESEARCH AND WORK WITH INDUSTRY AND UNIVERSITIES

The Navy's science and technology efforts focus on providing technology options for closure of warfighting gaps and developing breakthrough technological capabilities (avoiding technological surprise). The evolution to the all-electric ship will significantly expand our warfighting effectiveness through high-power weapons, launchers, countermeasures and defensive systems. Research efforts to develop and mature the technologies required for all-electric ships have been ongoing for a number of years.

The management of power on all-electric ships is based on an integrated power generation, distribution, and delivery system capable of providing power as required for all users – propulsion, sensors and weapons, and ship-service systems. A major barrier to achieving an all-electric naval force is the power density of electric generation, conversion and propulsion systems. Electric machines and conversion equipment used in electric drive ships are heavier and take up more volume than mechanical drive systems, limiting our ability to fully implement this technology in all of our ships. The Navy has a

wide range of research and development initiatives focused on improving the power density of integrated power systems, as well as on innovative hull forms and advanced propulsor designs to maximize the potential offered by the all-electric warship.

The exploitation of emerging breakthroughs in technologies for power generation and utilization (propulsion motors and launchers), power management (conversion and motor drives) and distribution, as well as advanced hull forms and drag reduction is needed to take full advantage of the efficiency and capabilities offered by an all-electric naval force. A ship design that takes advantage of the benefits of integrated shipboard power architecture; an advanced hull form and an advanced propulsor will enable significant improvements to war-fighting capability, survivability, and reductions in total ownership cost.

The ship-arrangement flexibility permitted by power-dense integrated electric power systems will expand the trade space for ship designs and enable lower cost ships. For surface ships, designs being considered offer the potential simultaneously to reduce drag in the range of 10 to 20 percent, increase fuel efficiency by as much as 50 percent, and reduce noise and heat loss by 50 percent—all of which reduce crew workload.

Continued research in the technology areas mentioned below should enable the war-fighting and efficiency benefits discussed above.

Fuel cells are electrochemical devices that convert a fuel's chemical energy directly to electrical energy. Fuel cells, with no internal moving parts, electrochemically combine a fuel, typically hydrogen derived from Navy distillate, and an oxidant without traditional combustion products, thereby dispensing with the inefficiencies and pollution of traditional energy conversion systems. Fuel cells are expected to be highly efficient, in the range of 35 percent to 50 percent, for the conversion process.

Thermoelectric (TE), thermophotovoltaic (TPV), and thermionic technologies are being investigated for their potential use for supporting long-term replacements for the steam plants aboard Navy ships to convert heat directly to electrical energy. The primary focus is on TE and TPV. The long-term goal is to achieve an overall system conversion efficiency of 20 percent, with hot-side temperature of approximately 600-800°C and cold-side temperature of approximately 50°C. Advances in TE technologies also will enable efficient generation of electrical power through waste-heat recuperation for vehicles and for distributed or remote power applications.

Superconducting machinery offers greater magnetic strength than current conventional machines. The use of superconducting machinery is expected to reduce the size and weight of large motors by at least 50 percent and of generators by approximately 30 percent. A five megawatt (MW) high-temperature superconducting (HTS) synchronous alternating current motor was designed, built and tested for ONR at a university center for advanced power systems under the auspices of ONR's Electric Ship Research and Development Consortium. Building on the successful completion of those tests, a full-

scale 36.5 MW HTS motor is being built and tested that could save as much as 62.5 percent in weight over motors now in use. ONR is also pursuing a 36.5 MW direct-current homopolar motor design.

Power-conversion equipment, based on a modular “Power-Electronics Building Block” approach, utilizing commercial off the shelf (COTS) elements, will enable efficient and dependable delivery of electrical power to propulsion systems and mission-critical equipment, including high-power weapons and sensors. Advanced system concepts for distribution and power management using this technology will be embedded in reconfigurable zonal systems that provide mission flexibility and dynamic reconfigurability. To support these concepts research is being pursued on medium- and high-voltage distribution, power-electronic building blocks, advanced converter/inverter topologies for power conversion and motor drives, solid-state circuit breakers, power control centers, advanced solid-state power switching devices utilizing wide-bandgap semiconductors, and advanced cables and power ducts.

High capacity energy storage devices need to have increased energy and power density, increased reliability, and improved safety. Technologies being considered to satisfy these goals include advanced batteries, pulsed alternators, and high-energy density components. Research investments are being made in advanced materials to identify more effective dielectric and magnetic materials that will permit increasing the density of capacitors, inductors, and transformers, both for pure energy storage and for filtering applications in power electronic systems.

Conventional propellers produce significant performance-degrading cavitation at speeds above 35 knots. Waterjets operate efficiently in the 30- to 60-knot speed range, but are not efficient below 20 knots, and often cannot meet transom installation requirements. Future ships will require high-power density, efficiency over the entire operating speed range, and robust designs and materials durable enough to last through 12-year Navy maintenance cycles. Research is being pursued on an advanced waterjet, AWJ-21, that discharges water below the free surface, and on axial-flow waterjets that have the potential to reduce ship installation impact and improve performance. Podded propulsors are used increasingly in the commercial sectors, including cruise ships and container ships. Several research efforts have evaluated the RimJet and an advanced ducted-electric propulsion pod.

Hull form plays an important role in seakeeping characteristics and reducing fuel consumption by reducing drag. Extensive research is being pursued on advanced hull forms and in drag reduction. ONR has invested in the construction of several small-scale vehicles to evaluate advanced hull forms.

Effective design tools are necessary to evaluate thoroughly and cost effectively the multiple design options for ship equipment and ship-system control components. Research to expand and improve the design tools required for ship design is being pursued. This capability will support thorough analysis of variants, technology-impact

evaluation, and prudent decision-making on investments for major developments. It also will streamline the transition of Navy-developed technology to shipbuilders and reduce the need for expenditures on physical model testing.

The research noted above is only a part of the overall effort to improve the Navy's war-fighting capability. These research initiatives seek to increase the power density, energy density, and efficiency of the entire shipboard power architecture in order to reduce power-system weight and provide new flexibility for ship arrangement, permitting increased payloads. These payoffs, coupled with improved hull forms capable of higher speeds and improved seakeeping, promise to increase war-fighting capability and reduce ship size to meet cost goals. However, significant development gaps remain for the technology areas discussed, the challenges are complex but the Navy continues to pursue solutions through collaborative partnerships with industry and academia.

IMPROVING ON EXISTING EFFICIENCY

Analyzing the cost of a ship is more than looking at the construction and outfitting or sail away cost. The cost of personnel is higher than any other cost in the life of a surface ship. The total cost of fuel, food, maintenance, parts, etc. does not amount to the personnel cost for manning our ships. Given those facts, we look to be more efficient in areas beyond fuel savings as today's budgets get tighter. Our Force Structure Strategy is a balance between New Construction and Modernization. Over the next thirty years it is critical for us to have a vigorous modernization program to achieve the expected service life of our ships in the face of rapidly escalating global threats using advanced

technologies. Modernization gets the most out of our capital investments and provides a buffer against the uncertainties of new construction funding. As we modernize, we are working to achieve savings throughout the life of our ships.

ARLEIGH BURKE (DDG 51) CLASS DESTROYER MODERNIZATION

The Fiscal Year 2007 Budget request includes \$16M in RDT&E, N and OP-N appropriations to continue the process to bring needed mid-life DDG modernization enhancements to the mainstay of our surface fleet. The DDG Modernization Program will ensure that each ship in the Class remains an affordable and viable warfighting asset throughout the entire projected 35-year service life. It is designed to reduce total ownership costs across the entire Class through significant reductions in manning requirements and the application of technology to achieve improved quality of life for Sailors, increased survivability, and improved maintainability. DDG 51 is scheduled to be the first legacy destroyer to receive the modernization upgrade in Fiscal Year 2010.

TICONDEROGA (CG 47) CLASS CRUISER MODERNIZATION PLAN

The Fiscal Year 2007 Budget request includes \$359M across multiple appropriations to procure long lead time material for the modernization of TICONDEROGA Class cruisers occurring in Fiscal Years 2008 and 2009. The CG Modernization program was restructured in Fiscal Year 2006 in accordance with Congressional direction. Under the restructured plan, the older Baseline 2 and 3 ships will be modernized first. Funding began in Fiscal Year 2006 for long lead-time procurements for a Fiscal Year 2008 Baseline 2 modernization availability of USS BUNKER HILL (CG 52). The Navy's plan will permit these ships to realize their expected service life of 35 years and substantially

increase combat capability of all remaining 22 CG 47 Class ships to pace the threat. This modernization will reduce combat system and computer maintenance costs, replace obsolete combat systems, and extend mission relevance. It will also incorporate manpower improvements and quality of service enhancements from the smart-ship program.

CONCLUSION

Challenging our own assumptions has been and remains essential to charting the right course in our Navy. Clearly, many factors are involved in determining and charting the right course with respect to the methods of ship propulsion for Navy vessels. Today's Navy panel represents a small but important part of the Navy talent and commitment associated with this complex and multi-dimensional matter.

With respect to the efforts on the Fiscal Year 2006 study, be assured that the Navy is not undertaking this analysis with any pre-determined outcomes in mind. Also, because the analysis is a work in progress, we have not reached any formal conclusions or identified any formal recommendations. Following the completion of the objective technical analysis of alternative propulsion methods required by Section 130, the results will be reviewed within the Department of the Navy, mindful of the requirement for the Secretary of the Navy to provide the results of the analysis, along with formal conclusions and recommendations in the report that is due to the congressional defense committees by November 1, 2006.

The Navy of the future must be a capabilities-based and threat oriented force. As the force of tomorrow is built we have incorporated innovation throughout the entire platform and not just the propulsion plant. The Fleet Response Plan, the Sea Swap Experiment, and forward posturing are sourcing initiatives that increase operational availability and reduce cost to the Navy. As the CNO has stated “America is a maritime nation. We NEED a strong Navy. We ARE a strong Navy.”

We appreciate the opportunity to appear before the subcommittee and stand ready to answer any questions the members of the subcommittee may have.