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HOUSE ARMED SERVICES COMMITTEE
SEAPOWER AND EXPEDITIONARY FORCES
SUBCOMMITTEE

STATEMENT OF

THE HONORABLE DR. DELORES M. ETTER
ASSISTANT SECRETARY OF THE NAVY
(RESEARCH, DEVELOPMENT AND ACQUISITION)

and

VADM PAUL E. SULLIVAN, U.S. NAVY
COMMANDER, NAVAL SEA SYSTEMS COMMAND

and

VADM JONATHAN W. GREENERT
DEPUTY CHIEF OF NAVAL OPERATIONS
INTEGRATION OF CAPABILITIES AND RESOURCES

and

RADM BARRY J. McCULLOUGH, U.S. NAVY
DIRECTOR OF SURFACE WARFARE

BEFORE THE

SEAPOWER AND EXPEDITIONARY FORCES SUBCOMMITTEE

OF THE

HOUSE ARMED SERVICES COMMITTEE

ON

INTEGRATED NUCLEAR POWER SYSTEMS FOR FUTURE NAVAL SURFACE COMBATANTS

MARCH 1, 2007

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Assistant Secretary of the Navy
(Research, Development and Acquisition)

The Honorable Delores M. Etter

Dr. Etter was nominated on September 6, 2005 by President George W. Bush to serve as the Assistant Secretary of the Navy for Research, Development and Acquisition. Dr. Etter was then sworn in on November 7, 2005. As the Navy's Senior Acquisition Executive, Dr. Etter is responsible for research, development, and acquisition within the Department of the Navy. From August 2001 to November 2005, Dr. Etter was a member of the Electrical Engineering faculty at the United States Naval Academy. She was also the first recipient of the Office of Naval Research Distinguished Chair in Science and Technology. Her academic interests were in digital signal processing and communications. Her research interests included biometric signal processing, with an emphasis on identification using iris recognition. She has also written several textbooks on computer languages and software engineering.

From June 1998 through July 2001, Dr. Etter served as the Deputy Under Secretary of Defense for Science and Technology. In that position, she was responsible for Defense Science and Technology strategic planning, budget allocation, and program execution and evaluation for the DoD Science and Technology Program. Dr. Etter was the Principal U.S. representative to the NATO Research and Technology Board. She was also responsible for the Defense Modeling and Simulation Organization, the High Performance Computing Modernization Office, and for technical oversight of the Software Engineering Institute. Dr. Etter was also the senior civilian in charge of the DoD high-energy laser research program.

From 1990-98, Dr. Etter was a Professor of Electrical and Computer Engineering at the University of Colorado, Boulder. During 1979-89, Dr. Etter was a faculty member in Electrical and Computer Engineering at the University of New Mexico. She served as Associate Vice President for Academic Affairs in 1989. During the 1983-84 academic year she was a National Science Foundation Visiting Professor in the Information Systems Laboratory in the Electrical Engineering Department at Stanford University.

Dr. Etter is a member of the National Academy of Engineering. She is also a former member of the National Science Board and the Defense Science Board. She is a Fellow of the Institute of Electrical and Electronic Engineers (IEEE), the American Association for the Advancement of Science (AAAS), and the American Society for Engineering Education (ASEE). She served as President of the IEEE Acoustics, Speech, and Signal Processing Society from 1988-89, and was Editor-in-Chief of the IEEE Transactions on Signal Processing from 1993-95.

Dr. Etter was a member of the Naval Research Advisory Committee from 1991-97, and chaired the committee from 1995-97. She has received the Department of the Navy Distinguished Public Service Award, the Secretary of Defense Outstanding Public Service Medal, and the Department of Defense Distinguished Public Service Medal.

United States Navy Biography

Vice Admiral Paul E. Sullivan
Commander Naval Sea Systems Command

A native of Chatham, N.J., Vice Admiral Sullivan graduated from the U.S. Naval Academy in 1974 with a Bachelor of Science degree in Mathematics.

Vice Adm. Sullivan served in *USS Detector* (MSO 429) where he earned his Surface Warfare Qualification. After transferring to the Engineering Duty Officer Community, he served at the Norfolk Naval Shipyard, Naval Sea Systems Command, Supervisor of Shipbuilding in Groton, Conn. and on the staff of the Assistant Secretary of the Navy (Research, Development and Acquisition). During his engineering duty assignments Adm. Sullivan earned his Submarine Engineering Duty Officer Qualification.

Vice Adm. Sullivan holds dual degrees of Master of Science (Naval Architecture and Marine Engineering) and Ocean Engineer from Massachusetts Institute of Technology.

Vice Adm. Sullivan served as program manager of the *Seawolf*-class Submarine Program (PMS 350) and the *Virginia*-class Submarine Program (PMS 450).

Upon selection to flag rank, Vice Adm. Sullivan served as Deputy Commander for Ship Design Integration and Engineering, Naval Sea Systems Command from 2001 to 2005.

Vice Adm. Sullivan became the 41st Commander, Naval Sea Systems Command in July 2005.

United States Navy Biography

Vice Admiral Jonathan W. Greenert
Deputy Chief of Naval Operations for Integration of Capabilities and Resources, OPNAV N8

Vice Admiral Jonathan W. Greenert, is a native of Butler, Pa. He graduated from the U.S. Naval Academy in 1975 and completed studies in nuclear power for service as a submarine officer.

His career as a submariner includes assignments aboard *USS Flying Fish* (SSN 673), *USS Tautog* (SSN 639), Submarine NR-1 and *USS Michigan* (SSN 727 - Gold Crew), culminating in command of *USS Honolulu* (SSN 718) from March, 1991 to July, 1993.

Subsequent fleet command assignments include Commander, Submarine Squadron 11, Commander, U.S. Naval Forces Marianas and Commander, U.S. 7th Fleet (August 2004 to September 2006).

Vice Adm. Greenert has served in various fleet support and financial management positions, including Deputy Commander, U.S. Pacific Fleet; Chief of Staff, U.S. Seventh Fleet; Head, Navy Programming Branch and Director, Operations Division Navy Comptroller.

He is a recipient of various personal, and campaign awards including the Distinguished Service Medal (3 awards), Defense Superior Service Medal and Legion of Merit (4 awards). In 1992 he was awarded the Vice Admiral Stockdale Award for inspirational leadership. He considers those awards earned throughout his career associated with unit performance to be most satisfying and representative of naval service.

United States Navy Biography

Rear Admiral Bernard J. "Barry" McCullough
Director, Surface Warfare (CNO N86)

From Weirton, W.Va., Rear Admiral Bernard J. "Barry" McCullough graduated from the United States Naval Academy with a Bachelor of Science Degree in Naval Architecture and was commissioned on 4 June 1975. Additionally, Rear Adm. McCullough completed Naval Nuclear Power training and received a Master of Science degree in Strategic Resource Management from the Industrial College of the Armed Forces at National Defense University.

Most recently, Rear Adm. McCullough was Commander, Carrier Strike Groups Six/Commander *USS John F. Kennedy* Strike Group. He also served as Commander Carrier Strike Group Fourteen/Commander *USS Enterprise* Strike Group. Rear Adm. McCullough's major command was in *USS Normandy* (CG 60) from February 1999 until February 2001.

Prior to commanding *Normandy*, he served as Commanding Officer in *USS Scott* (DDG 995) and *USS Gemini* (PHM 6). Other sea assignments were: Operations Officer for Commander Second Fleet/Striking Fleet Atlantic, Engineer Officer in *USS Enterprise* (CVN 65), Engineer Officer in *USS Virginia* (CGN 38), and Main Propulsion Assistant in *USS Texas* (CGN 39).

Rear Adm. McCullough's shore tours include serving as Commander, Navy Region Hawaii and Naval Surface Group Middle Pacific, the Director for Strategy and Analysis, J5, at U.S. Joint Forces Command, First Battalion Officer at the United States Naval Academy and as the Department Head for the D1G Prototype Nuclear Power Plant at Nuclear Power Training Unit, Ballston Spa, N.Y. Rear Adm. McCullough assumed his current responsibilities as Director, Surface Warfare in July, 2005.

His decorations and awards include: Defense Superior Service Medal, Legion of Merit, Defense Meritorious Service Medal, Meritorious Service Medal, Navy Commendation Medal, and Navy Achievement Medal. Additionally, he is authorized to wear numerous unit and campaign awards.

INTRODUCTION

Mr. Chairman, distinguished members of the Seapower and Expeditionary Forces Subcommittee, thank you for this opportunity to appear before you to discuss the topic of Integrated Nuclear Power Systems for Future Naval Surface Combatants.

First, we would like to thank you for your continued interest in naval shipbuilding and the future of our Navy. In particular, the discussion of power systems for future ships is vital, with significant implications for National strategic interests, for the capabilities of our Navy, and for our ability to acquire and support our Navy in a cost effective manner.

The Subcommittee asked that the Navy address a range of topics associated with the possible incorporation of nuclear power systems in future surface combatants. Admiral Donald, Director, Naval Nuclear Propulsion, has addressed the topics of training of Navy nuclear propulsion operators, adapting an existing reactor design for new applications, nuclear shipbuilding infrastructure issues, and the cost savings that might be realized from increased order quantity of major reactor plant components. Additional topics will now be addressed, including the conclusions and recommendations of the alternative propulsion report to Congress delivered on January 12, 2007, the acquisition vs. life cycle cost tradeoffs for nuclear powered designs, the warfighting implications of operating nuclear vice fossil-fueled warships, and amplifying information on the shipbuilding infrastructure discussion provided by ADM Donald.

CONCLUSIONS AND RECOMMENDATIONS OF THE NAVY'S FISCAL YEAR 2006 ALTERNATIVE PROPULSION STUDY

Section 130 of the National Defense Authorization Act (NDAA) for Fiscal Year 2006 directed that the Navy provide a report on alternative propulsion methods for surface combatants and amphibious warfare ships. Section 130 identified several important and detailed matters to be addressed, including: the key assumptions used in carrying out the analysis; the methodology and techniques used in conducting the analysis; a description of current and future technology relating to surface ship propulsion; a description of each propulsion alternative and an analysis and evaluation of each such alternative from an operational and cost-effectiveness standpoint; a comparison of the life-cycle costs of each propulsion alternative; an analysis of when the nuclear propulsion alternative becomes cost effective as the price of a barrel of crude oil increases ("break-even" analysis); conclusions and recommendations of the study; and the Secretary's intended actions, if any, for implementation of the conclusions and recommendations of the study.

Guided by the Section 130 language, the FY 2006 Alternative Propulsion Study explored power systems in amphibious warfare ships, medium surface combatants (multi-mission air defense) and small surface combatants. Multiple ship/propulsion system concepts were evaluated on the basis of life-cycle cost and operational effectiveness. The study considered nuclear, gas turbine and diesel power sources, mechanical and electric drive, various types of propellers and podded propulsor systems, and other innovative concepts. The study incorporated technology that is anticipated to be mature enough for transition to ship acquisition programs in the next twenty years.

The three types of ship concepts in this report do not reflect the requirements of any current or planned Program of Record ship. Instead, they serve as boundaries of the analytical trade space for ongoing and future ship design efforts.

The primary results of this study are:

- Ship displacement is not a good criterion for selecting the technology for power and propulsion systems. Rather, lifetime and peak energy requirements drive the selection of power and propulsion systems.
- Operational Tempo and Operating Profile significantly impact the break-even analysis of nuclear versus fossil fuel power and propulsion system alternatives.
- Nuclear ship alternatives have higher ship construction costs (5th ship ~\$600M - \$800M premium in FY 2007 dollars) but have lower operating and support costs when fuel costs are considered.
- Life-cycle cost break-even analysis (\$70/BBL - \$225/BBL) for Medium Surface Combatants displacing roughly 21,000 to 26,000 metric tons indicates that nuclear power should be considered for near term applications.
- Life-cycle cost break-even analysis for Small Surface Combatants (\$210/BBL - \$670/BBL) and Amphibious Warfare Ships (\$210/BBL - \$290/BBL) indicates that life-cycle cost will not drive selection of nuclear power for these ships.
- Alternative fossil fuel power and propulsion architectures can reduce life-cycle cost over all current gas turbine plant architectures.
- Ship vulnerability performance can be significantly improved with architecture improvements associated with zonal distribution, integrated power systems, and longitudinally separated propulsion equipment.
- Nuclear powered ship alternatives provide operational benefits in surge to theater timelines and operational presence (time on station).
- The amount of fuel required for transit and on-station operations of fossil-fueled ships can be reduced with use of more efficient propulsors, drag reduction, high efficiency prime movers and combined plants with boost prime movers.

LIFE CYCLE COSTS VS. ACQUISITION COSTS OF NUCLEAR POWERED COMBATANTS

The Report to Congress presents a break-even analysis using a fifth ship life cycle cost perspective. As such, the results are meant to merely indicate conditions where nuclear propulsion should be considered in future analyses. These future analyses will trade off non-recurring costs with overall force structure requirements, such as quantity, to determine specific break-even points.

For the ship concepts developed for the Report to Congress, the acquisition cost premium of the 5th ship in Fiscal Year 2007 dollars for nuclear power is estimated as:

- Small Surface Combatants ~80% (~\$600M)
- Medium Surface Combatants ~22% (~\$600M-\$700M)
- Amphibious Warfare Ships ~46% (~\$800M)

Based on fuel usage projections, the break-even costs per barrel of crude oil at which nuclear propulsion becomes economical on a LCC basis for the various options in Fiscal Year 2007 dollars are:

- Small Surface Combatants: $210/BBL to $670/BBL
- Medium Surface Combatants: $70/BBL to $225/BBL
- Amphibious Warfare Ships: $210/BBL to $290/BBL

The baseline market price of fuel used in this analysis is the current Defense Energy Support Center rate of $74.15/BBL of crude oil, and its burdening buildup results in a delivered-at-sea cost of DFM F76 of $152.95/BBL. Based on fuel usage projections, the life cycle cost premiums for nuclear propulsion compared to fossil fuel propulsion are:

- Small Surface Combatants: 17% to 37%
- Medium Surface Combatants: 0% to 10%
- Amphibious Warfare Ships: 7% to 8%

From this analysis, a nuclear Medium Surface Combatant is the most likely of the three ship concept types studied to prove economical depending on the operational profile and operational tempo that the ship actually experiences.

The finding (that nuclear power should be considered for a Medium Surface Combatants) is consistent with inclusion of nuclear powered variants in the CG(X) Analysis of Alternatives, to be completed in Fiscal Year 2007.

WARFIGHTING IMPLICATIONS OF NUCLEAR VICE FOSSIL FUEL POWERED SHIPS

FORCE STRUCTURE BACKGROUND

In 2005, in conjunction with the Quadrennial Defense Review (QDR), the Navy conducted analysis of the operational risks associated with the 2006 Defense planning guidance. An outcome of this analysis was the development of a long range shipbuilding plan characterized by affordability, stability and the capability to outpace the threat anticipated in the 2020 timeframe with acceptable risk. In February 2006, Navy introduced the 313-Ship Force based on a requisite 30-year shipbuilding plan.

Key tenets of the 313-Ship Force have been stability and affordability of the Navy's long-range shipbuilding plan. The Navy's commitment to a stable shipbuilding profile is reflected in the commitment to the individual ship build rates and specific classes included in the near-term. Consequently, there have been no changes in the Navy's force structure requirements in the FY 2008 annual report. Further, the Navy continues to assess out-year requirements with a view toward providing industry with a predictable and executable plan upon which they may plan modernizing their facilities and improving production processes. Accordingly, some adjustments have been made in long-range procurement plans to balance requirements with affordability and industrial base stability.

FORCE STRUCTURE REQUIREMENTS AND SHIP POWER SYSTEMS

The 313-Ship Force is founded on a capabilities-based approach, measured with expected Joint Force demands in peacetime operation and the most stressing construct of the Defense planning guidance. The resultant capabilities-based, threat-oriented force will be able to be disaggregated and distributed world wide as necessary to support Combatant Commander Global War on Terror (GWOT) demands, and rapidly and effectively aggregated to provide the capability needed to dissuade, deter or defeat any potential adversary in a Major Campaign Operation (MCO). Although not explicitly modeled in campaign analysis, some assumptions regarding ship propulsion and electrical distribution systems are made. For instance, campaign analyses assume that ships will be able to surge from homeport or "swing" between theaters on a timeline commensurate with their designed speed and range. At the mission and tactical level, speed, regardless of propulsion plant, is a key factor for success and survivability. Finally, it must be assumed a ship can meet the electrical power generating requirements for installed sensor and weapon systems.

MISSION EFFECTIVENESS ANALYSIS IN THE FY 2006 ALTERNATIVE PROPULSION REPORT

Although the Navy has not modeled fossil-fueled versus nuclear ship in the MCO analysis, the Report to Congress on the Alternative Propulsion Methods for Surface Combatants and Amphibious Warfare Ships did look at elements of operational effectiveness. Specifically, the report analysis includes the projections of increased ship electrical loads. Additionally, three elements of operational effectiveness were modeled in the study and compared using accompanying metrics: surge to theater (timeliness), operational presence (availability) and vulnerability (probability of loss of mission capabilities).

The FY 2006 study analyses (for break-even costs and mission effectiveness) did include the impacts of significantly increased electrical loads including a consideration of future mission systems. In the particular case of the Medium Surface Combatant modeled, the significant increase in ship service loads is attributable to Theater Ballistic Missile Defense (TBMD) radar system requirements. Energy requirements for each ship type were based on Design Reference Missions (DRM's) derived from the DoD 2012 Baseline Security Posture (BSP) and the 2010-2014 MCO scenarios. These DRM's were comprised of Tactical and Operational Situations. These situations drove energy demand predictions based on mobility, survivability, and mission system energy demands. Warfare mission system loads that are continuously active drive the service electrical loads. Pulsed power weapons were not specifically modeled in the study as the energy consumption profiles and power system demands of future directed energy and electric weapons are not currently known.

The study modeled surge to theater (timeliness), operational presence (availability) and vulnerability (probability of loss of mission capabilities). Surge to theater was reviewed in terms of quantity of fuel and number of refuelings for high speed transits, plus maximum transit endurance without refueling. Systems that provide high-energy storage capacity and density, high energy conversion (i.e. engine) efficiencies and high thrust generation (i.e. propulsor) efficiencies improve performance relative to these metrics. Nuclear powered ships are superior to all fossil fuel variants in the transit scenarios modeled. Other technologies providing high levels of performance relative to the mission timeliness metric are diesel prime movers and single screw propulsors.

Operational presence was evaluated as the time a ship concept variant can remain on station while conducting missions in theater. DoD Defense Planning Scenarios provided the basis for the speed time profile and ship service electric loads modeled in the operational presence analysis. The nuclear powered variants are superior to fossil fuel powered variants in providing operational presence on station. Limiting factors for time on station for nuclear powered variants include ship stores and aviation fuel capacities. Fossil fuel plant variants with diesel prime movers have a significant advantage over gas turbine variants. The best performing small surface combatant fossil fuel variant studied is a mechanical-electric drive single shaft variant. This variant best captures the system efficiencies and flexibility provided by an Integrated Power System (IPS). Similar improvements in operational presence can be expected by employing hybrid IPS architectures.

Operational presence is improved through the inclusion of increased fuel tankage, albeit at increased acquisition and life cycle costs. The fossil fuel ships evaluated in this study were designed with fuel tankage capacities that are higher than traditional capacities. Nuclear ship options dominated these ships in surge and presence metrics, and would be even more dominant in comparison to current fleet ships.

Vulnerability is the probability of losing mission capability following damage from threat weapons. The vulnerability assessments demonstrated that both fossil-fueled and nuclear system architectures can be designed to similar vulnerability postures. Results of ship vulnerability assessment studies suggest that power and propulsion systems and architectures reduce ship vulnerability through redundancy, zonal distribution systems, separated distribution of propulsion systems, and flexible energy conversion systems providing for distributed conversion architectures.

Longitudinally separated propulsors as enabled by IPS and hybrid propulsion plants were the single largest discriminator among surface combatant variants in the vulnerability analysis. Since the life-cycle cost analysis did not significantly discriminate between IPS and mechanical drive plants, future surface combatant designs should consider IPS and hybrid propulsion plants, both fossil and nuclear.

ANALYSIS OF ALTERNATIVES OVERVIEW

While the use of analyses to support programmatic decisions is not new, the analysis of alternatives (AoA) process brings formality to the Concept Refinement phase by integrating the joint capabilities development and the pre-systems acquisition processes. In particular, the AoA process provides a forum for discussing risk, uncertainty, and the relative advantages and disadvantages of alternatives being considered to satisfy mission capabilities. The AoA shows the sensitivity of each alternative to possible changes in key assumptions (e.g., threat) or variable (e.g., performance capabilities) and represents one way for the Milestone Decision Authority (MDA) to address issues and questions early in pre-systems acquisition and during a program's life-cycle.

Involvement of senior experienced, and empowered individuals from both the Chief of Naval Operations (CNO)/Commandant of the Marine Corps (CMC) and the acquisition communities play a key role in the analytical process. Periodic reviews prior to key decision points affords high-level visibility to potential programs, provides analytical rigor and flexibility for development of the initial acquisition strategy, and allows for coordination of effort between evolutionary increments and other defense programs. Review of in-progress analysis ensures the analysis addresses the key issues at hand and associated top-level architectural views, assumptions, and limitations.

In order to ensure proper oversight, in the case of the next generation cruiser (CG(X)) we have formalized the review process through the AoA Oversight Board (OSB). The OSB for CG(X) consists of Flag and General Officers and Senior Executives from Office of Secretary of Defense (Acquisition and Program Analysis), Deputy Assistant Secretary of the Navy for Ships, Deputy Assistant Secretary of the Navy for Integrated Warfare Systems, Naval Sea Systems Command, Naval Reactors, Navy Staff, Program Executive Offices (Ships and Integrated Warfare Systems), Joint Staff, and Aegis Ballistic Missile Defense Office. The OSB assists the Analysis Director in assessing the validity and completeness of key program issues, alternatives, assumptions, measures of effectiveness (MOEs), integration and interoperability issues, international participation, process redesign approaches, scenarios, concept of operations and threat characteristics.

The Maritime Air and Missile Defense of Joint Forces (MAMDJF) Initial Capabilities Document was reviewed and validated by the Joint Requirements Oversight Council (JROC) on May 1st, 2006. As part of the effort on CG(X), the Next Generation Cruiser, the Under Secretary for Defense (Acquisition, Technology, and Logistics), Kenneth Krieg directed, on June 16th, 2006, that an AoA examine the capabilities and cost of a range of options to address the gaps as defined in the MAMDJF . Additional AoA clarification was specified recently by the Secretary of the Navy who stated in the cover-letter for his Report to Congress on Alternative Propulsion Methods for Surface Combatants and Amphibious Warfare Ships, dated January 12, 2007, that "The ongoing Analysis of Alternatives for the Maritime Air and Missile Defense of the Joint Force capability, which will include recommendation of a CG(X) platform alternative, is incorporating the methods of this study, and is examining both fuel efficient fossil-fueled power plants and nuclear power alternatives. Again, the selection of power plant architecture for a particular class of ship must include analysis of the cross-program considerations described above." In response to Representative Taylor's question to the Secretary of the Navy on the study dated January 12, 2007, the Secretary responded that the AoA "includes efforts to review the potential use of nuclear propulsion. The AoA is scheduled to be completed this year, and will address the physical possibilities of incorporating a nuclear plant, the cost versus operational effectiveness, the value and need for increased electrical power to allow for future technologies, and impacts to the logistics force." When the CG(X) AoA is complete, it will provide the foundation for the Milestone A decision scheduled in late 2007 by Secretary Krieg, thus beginning the Technology Development Phase.

CONSTRUCTION OF NUCLEAR POWERED SURFACE COMBATANTS

The Navy currently builds large surface combatants primarily at two private shipyards, General Dynamic's (GD) Bath Iron Works (BIW) in Bath, Maine, and Northrop Grumman Ship Systems (NGSS) Ingalls Operations, in Pascagoula, Mississippi. Neither of these two shipyards is authorized by the Navy to conduct nuclear shipbuilding. Selection of nuclear power for a future surface combatant would require changes to the Navy's acquisition strategy for these ships and/or infrastructure modifications to the shipbuilding industrial base. The Committee has specifically asked that the Navy discuss infrastructure issues associated with:

1. Full construction at one nuclear certified shipyard. That is, a single shipyard would either construct the entire nuclear warship or would serve as the erecting yard for ship modules produced at non-nuclear certified yards,
2. Construction at multiple non-nuclear certified shipyards with final reactor core load and test at a certified facility, or
3. Complete construction, including core load and test at multiple nuclear certified shipyards.

The Navy has not studied procurement strategies or potential infrastructure modifications associated with the construction of a new class of cruisers, with or without nuclear power. The Navy has also not requested that industry, including current nuclear or non-nuclear certified shipyards, study this matter. Consequently, the discussion of these issues for this hearing will be at the conceptual level.

It is likely that any option pursued would incur near term costs associated with reduced efficiencies of ramping up new construction capabilities as well as possible integration of multiple shipyards into the construction process. The long term benefits, costs and impacts to both nuclear and non-nuclear industrial bases require more extensive evaluation to determine the most cost effective solution should procurement of nuclear powered surface combatants be pursued.

In his statement, ADM Donald, Director Naval Nuclear Propulsion, notes the attributes that are required for a shipyard to be deemed capable of building nuclear powered ships. Electric Boat (EB) and Northrop Grumman Newport News (NGNN) are the two qualified nuclear capable private shipyards. ADM Donald also notes that existing nuclear capable shipyards have sufficient capacity to accommodate construction of surface ship nuclear propulsion plants. Based on his testimony, only two viable shipbuilding strategies remain:

- Wholesale nuclear ship construction at a currently nuclear capable shipyard (i.e., EB, NGNN).
- Construction of the nuclear portions of the ship at a nuclear capable shipyard with construction of non-nuclear portions of the ship at existing surface ship construction yards. Location of final ship erection would require additional analysis.

The details of these options as well as cost and risk assessments have not yet been performed. The specific impacts on existing and planned workload in the existing private shipyards, learning curves, and inefficiencies of multiple design and construction organizations would have to be examined in detail.

Acquisition of nuclear powered surface combatants must address the primary issues of: *capability* of shipyards to conduct nuclear construction, *capacity* of the shipyards (facilities and labor resource loading), and *efficiency* impacts (positive or negative), particularly for split construction with erection at a single site.

Capability

- Both NGNN and EB should be capable of constructing nuclear powered surface ships.
- Improvements to both shipyards' infrastructure would need to be considered if the ship design necessitated.
- Although NGNN and EB are experienced builders of complex nuclear powered ships and submarines, the production processes and workforce qualifications necessary to build and test surface combatants would require assessment.

Capacity

- The workforce and facilities loading of NGNN or EB to accept the additional work of surface combatant production would need to be considered.
- Erection of the ships at a separate site from BIW or NGSS would have significant impact on those two shipyards' workload. Although still producing ship modules, the work associated with ship erection, completion of post-erection and launch outfitting, and integration and test of systems would transfer to the erection site.

Efficiency

- Although the practice of fabricating ship modules at multiple sites with erection at a single site has become common in Navy shipbuilding, this acquisition strategy would likely result in loss of efficiency. This is primarily due to the impacts of: the time required for and costs of transporting modules; interfaces between multiple separate design and production workforces; increased risk of rework associated with interface errors; and redundancies in oversight required (industry and Government) at multiple sites.
- Cost assessments would need to consider the overhead sharing impact of the increased workshare for the erection shipyard (improving cost share across programs) and the decreased workshare at the non-nuclear shipyard (higher cost share to other programs).

This area would require further detailed assessment by the Navy and industry to determine the most cost effective solution for procurement of a nuclear powered surface combatant if that path is pursued. The nonrecurring and recurring costs, schedules, component and shipyard industrial base impacts of all propulsion options being considered would be part of the Navy's assessment of the nuclear power alternative for future surface combatants.

CONCLUSION

The Navy's FY 2006 study on Alternative Propulsion Methods for Surface Combatants and Amphibious Warfare Ships demonstrated that the selection of a ship propulsion method is an extremely complex process with many variables, and is highly dependent on ship operational requirements. There is no optimum solution across ship classes. The study's cost effectiveness analysis for nuclear power demonstrates that the break-even fuel price is a bounded range vice a single point, with significant dependence on assumed operational tempo and the efficiency of conventional power alternatives.

The Navy also must always weigh the design decision for a single ship class against wider considerations, including: total ship procurement and life cycle costs and their impact on affordability of the overall shipbuilding plan; the capabilities and capacity of the shipbuilding industrial base; technology benefits and risks; and operational support considerations. In the case of increasing the use of nuclear power particularly, the Navy needs to evaluate the operational benefits versus the higher near-term costs. The volatile nature of fuel costs also requires consideration.

As recommended in the report, the Navy will continue to use the methods and processes described for future design analyses. Future analyses will include consideration of integrated power systems (such as in DDG 1000 and T-AKE), combined plant architectures (such as the diesel-gas turbine systems in the Littoral Combat Ships and LHD-8), and nuclear power.

The ongoing Analysis of Alternatives for the MAMDJF capability, which will include recommendation of a CG(X) platform alternative, is incorporating the methods of this study, and is examining both fuel efficient conventional power plants and nuclear power alternatives.

The Navy takes seriously the Subcommittee's desire that we carefully consider nuclear power for the CG(X) and other future platforms, and we share the Subcommittee's concern on the strategic implications of fossil fuel independence. The Navy will examine all of the factors discussed today when making future power system choices. We appreciate the opportunity to appear before the Subcommittee.