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INTEGRATED NUCLEAR POWER SYSTEMS FOR FUTURE NAVAL SURFACE COMBATANTS

HEARING

BEFORE THE

SEAPOWER AND EXPEDITIONARY FORCES SUBCOMMITTEE

OF THE

COMMITTEE ON ARMED SERVICES
HOUSE OF REPRESENTATIVES

ONE HUNDRED TENTH CONGRESS

FIRST SESSION

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INTEGRATED NUCLEAR POWER SYSTEMS FOR FUTURE NAVAL SURFACE COMBATANTS

HOUSE OF REPRESENTATIVES,
COMMITTEE ON ARMED SERVICES,
SEAPOWER AND EXPEDITIONARY FORCES SUBCOMMITTEE,
Washington, DC, Thursday, March 1, 2007.

The subcommittee met, pursuant to call, at 2:04 p.m., in room 2118, Rayburn House Office Building, Hon. Gene Taylor (chairman of the subcommittee) presiding.

OPENING STATEMENT OF HON. GENE TAYLOR, A REPRESENTATIVE FROM MISSISSIPPI, CHAIRMAN, SEAPOWER AND EXPEDITIONARY FORCES SUBCOMMITTEE

Mr. TAYLOR. Good afternoon.

I want to welcome our witnesses.

Captain Ebbs has done a magnificent job of preparing my opening statement. Since we are scheduled for votes in a half-hour, I am going to forego mine so we get a chance to go straight to our witnesses.

We want to welcome the Honorable Delores Etter, Assistant Secretary of the Navy for Research, Development and Acquisition; Admiral Kirk Donald, Director of the Naval Nuclear Propulsion Program; Vice Admiral Paul Sullivan, Commander, Naval Sea Systems Command; Vice Admiral Jonathon Greenert, Deputy Chief of Naval Operations for Integration and Capability and Resources; and Rear Admiral Barry McCullough, Director of the Surface Warfare Division.

Again, I am going to forego my opening statement because we want to hear from you. I am going to yield now to my ranking member, the great and wise Roscoe Bartlett.

STATEMENT OF HON. ROSCOE G. BARTLETT, A REPRESENTATIVE FROM MARYLAND, RANKING MEMBER, SEAPOWER AND EXPEDITIONARY FORCES SUBCOMMITTEE

Mr. BARTLETT. Thank you very much. I ask unanimous consent to submit my statement for the record.

Mr. TAYLOR. Without objection.

Mr. BARTLETT. Thank you very much.

I am happy you are here and look forward to your testimony. Thank you.

[The prepared statement of Mr. Bartlett can be found in the Appendix on page 37.]

Mr. TAYLOR. Again, given that we have about 25 minutes, and I am looking at five very smart people, Secretary Etter, would you like to begin?

STATEMENT OF HON. DR. DELORES M. ETTER, ASSISTANT SECRETARY OF THE NAVY (RESEARCH, DEVELOPMENT AND ACQUISITION); ADM. KIRKLAND H. DONALD, DIRECTOR, NAVAL NUCLEAR PROPULSION PROGRAM, U.S. NAVY; VICE ADM. JONATHAN W. GREENERT, DEPUTY CHIEF OF NAVAL OPERATIONS, INTEGRATION OF CAPABILITIES AND RESOURCES, U.S. NAVY; VICE ADM. PAUL E. SULLIVAN, COMMANDER, NAVAL SEA SYSTEMS COMMAND, U.S. NAVY; REAR ADM. BARRY J. MCCULLOUGH, DIRECTOR OF SURFACE WARFARE, U.S. NAVY

STATEMENT OF HON. DR. DELORES M. ETTER

Secretary ETTER. Thank you.

Chairman Taylor, Mr. Bartlett, and members of the subcommittee, thank you for the opportunity to appear before you today to discuss the topic of the potential use of integrated nuclear power systems for future naval surface combatants.

On behalf of myself and the others joining me, I would like to submit our written testimony for the record. Admiral Donald will have a separate statement to make.

I would like to begin by thanking the subcommittee for its keen interest in this topic. Next, I want to assure you that the Navy takes very seriously the strategic implications of the consideration of nuclear power for future ship platforms, which include operational effectiveness for our Navy and joint forces, and at the national level, the issue of fossil fuel demand.

As Admiral Donald will point out, our nuclear fleet of aircraft carriers and submarines has demonstrated significant operational flexibility in responding to the nation's needs. The advantages of nuclear power are a key factor included in the analysis of future platforms. However, the selection of a power plant for new ships must consider a wide range of issues. These issues include design factors for individual platforms, including performance and acquisition and life-cycle costs.

A platform decision must also be made in the larger context of overall force structure requirements, and of Navy-wide acquisition issues, including shipbuilding and the capabilities and capacity of our shipbuilding industrial base. The Navy recently submitted to Congress a report on alternative propulsion methods for surface combatants and amphibious warships. This comprehensive report addressed multiple ship and propulsion system concepts, including nuclear power, evaluating them on the basis of life-cycle costs and operational effectiveness.

In particular, the study determined the break-even points based on the price of crude oil when nuclear propulsion alternatives become cost-effective over the life-cycle, as compared to fossil-fueled alternatives. There were some very interesting conclusions.

First, the study confirmed that because nuclear ships can travel at high speeds for long periods without refueling, they can surge to theater quickly and spend more continuous time on-station after arriving. The study also drew several important conclusions when considering acquisition and life-cycle costs. I would like to discuss these in terms of costs to build the ship and power demand of the ship.

First, nuclear ships have overall lower operating and support costs because of their fuel independence, but are more expensive to build. The study found that this procurement premium ranged from between $600 million and $800 million per ship for the fifth ship of a class.

Also, when focusing on the life-cycle costs or the break-even point aspect of a ship power decision, it was clear that the energy requirements of a ship, not its physical size, as one might imagine, are the major driver in the selection of power systems. These energy requirements are dependent on the power demand of the combat system and also on how much time the ship will spend at sea, and at what speeds.

Based on these projected energy demands, the life-cycle break-even points for small surface combatants ranged from $210 per barrel to $670 per barrel, and for amphibious ships ranged from $210 per barrel to $290 per barrel. Consequently, life-cycle cost savings alone are unlikely to drive selection of nuclear power for these ships.

However, for medium surface combatants, with their anticipated high-combat system energy demands, this break-even point is between $70 per barrel and $225 per barrel. This indicates that nuclear power should be considered for near-term applications for those ships.

The Navy is currently preparing an analysis of alternatives for a new class of surface combatants, CGX. If the cost and power requirements support consideration of a nuclear propulsion system, the Navy must also carefully consider the construction strategies for a nuclear surface combatant. Issues include the fact that neither General Dynamics, Bath Iron Works, or Northrop Grumman Ship Systems Ingalls, our nation's two suppliers of large surface combatants, are authorized by the Navy to conduct nuclear shipbuilding.

Currently, construction of the nuclear portions of any surface combatant would need to be done at one of the two shipyards authorized to do such work: Northrop Grumman Newport News and General Dynamics Electric Boat. The specific implications of such a strategy on the existing and planned workload of each of these private shipyards have not been determined.

Also, the Navy would need to conduct a detailed assessment of the risk and cost impacts of a potential splitting of the design and construction of a nuclear-powered surface combatant between nuclear- and non-nuclear-capable shipyards.

To conclude, the selection of a power system for our Navy's future surface combatants is an extremely complex process, with many variables both at the ship platform and Navy-wide level. There is no optimum solution across all platforms. In providing our recent report to you, the Secretary of the Navy affirmed that we would use the methods in the report for future design analysis, and this would start with the CGX cruiser.

Again, the Navy fully appreciates the operational advantages of nuclear power, particularly for ships with high energy demands. We also take seriously the strategic implications of increased fossil fuel independence. These will be considerations in our decision for future ships.

With that, we thank you again for the opportunity to appear before the subcommittee, and we would be pleased to answer any questions. Thank you.

[The prepared statement of Ms. Etter, Admiral Sullivan, Admiral Greenert, and Admiral McCullough can be found in the Appendix on page 55.]

Mr. TAYLOR. Thank you, Madam Secretary.

The chair now recognizes Admiral Donald.

STATEMENT OF ADM. KIRKLAND H. DONALD

Admiral DONALD. Thank you very much. I have a brief statement I would like to offer for the record.

Mr. TAYLOR. Certainly, Admiral. Because we have, with the great help of our ranking member, foregone on our opening statements, feel free to speak as long as you wish.

Admiral DONALD. Thank you, sir. I have prepared a briefing on the basics of naval nuclear propulsion. I would like to give that at this time, and I will come back and give my opening statement.

Good afternoon, Mr. Chairman. Thank you very much for the opportunity to appear before the committee and discuss the Naval Nuclear Propulsion Program. I have prepared a briefing on the basics of naval nuclear reactors and how they actually work. To do this, I have brought a couple of props with me today.

The first one being this model, a model that was used by Admiral Rickover in 1951, in the early days of the naval nuclear propulsion program when he was giving briefings widely to wide audiences, including national television, on how his technology, the pressurized water reactor, could be employed on a warship and specifically the submarine. At this time, the Nautilus was more concept than it was ship, because the ship did not go to sea until 1955.

Fundamentally, what he chose for the power plant for the ship was what we call a pressurized water reactor. To describe that a little bit better, I have a diagram here on my left that may give you a few more details. The pressurized water reactor cycle really includes two distinct cycles, the first being a primary cycle, which includes this area here with the reactor. It is the heat source and its associated equipment provides the heat to convert the steam that we need to drive the turbines. If you think of it, it is like a fire-box in a boiler in a traditional ship today.

That heat energy is translated into steam in this piece of equipment here, a steam generator. That steam is then translated into the secondary plant, which is the second cycle that is used to drive turbines. The key issue here, the key point of design, is that the two cycles are separate in that the water in the primary cycle, which is high-pressure water that flows through the reactor, is separated from the water that flows in the secondary plant at a lower pressure and is converted to steam.

The key to that technology is the team generator that you see in there. Again, it is a heat exchanger. The steam that is generated in the heat exchanger by contact with the piping that contains that high-energy water from the reactor goes into propulsion equipment and electrical equipment to generate the electrical power that is needed for the crew, for the weapons systems, for the combat systems on the ship, and it goes to drive the propulsion train.

In the report, you will see there is a discussion about mechanical propulsion and integrated propulsion systems. Mechanical uses turbines with reduction gears, a mechanical reduction system to drive the propeller directly. Integrated propulsion systems use another electrical generator that drives a motor that drives the propeller itself.

We have had experiments. We have done testing. In fact, we have prototyped electric drive in submarines before. It is a technology we are familiar with. The next generation of surface craft, the DDG–1000, would use an integrated propulsion system of that nature. At any rate, the steam system would be the same to supply the steam to the driving turbines.

A couple of key points about this area here in the reactor compartment. This reactor is obviously the heat source for this cycle. It uses the fission of uranium to generate the heat that heats the water up. That uranium, in the case of our submarines, is loaded in the beginning of the construction of the ship and it is never refueled.

If you compare that to this ship, the Nautilus, her first core when she went to sea in 1955, she had to come back into port in 1957 to be refueled. We don't do that on our submarines anymore. On our aircraft carriers, we do have one mid-life refueling, typically at the 20- to 25-year point, to continue the life of the ship out to 40 to 50 years.

The other thing that is noteworthy about this cycle is that the water, the high-pressure, high-temperature water that flows through the reactor, is completely contained inside a welded boundary. So when the water flows out of the reactor in to the steam generator, it flows inside high-strength, high-integrity tubes that maintain that water contained in the primary plant.

The reason for that is to not have the water flowing through the core, which could be potentially radioactive, which will be radioactive, not come in contact with the water and the steam that will eventually be in the propulsion spaces, which is normally occupied by operators. The reactor compartment is not occupied during reactor operations.

The other thing to recognize is that all of the equipment in the primary cycle is contained inside what we call the "reactor compartment." It is a shielded volume that is not occupied during reactor operations because of the high radiation levels. However, the shielding contains that radiation inside the compartment, and it does not affect the operators who routinely operate in the engineering spaces.

So between not having the radioactive water contacted with the steam that is in the propulsion spaces, and having the shielded protection from the reactor, our operators operate in the vicinity of this bulkhead right here, this compartment, for months at a time without exceeding radiation levels that are allowed by law. In fact, an operator on a submarine would get less radiation in the course of a day's duty on a submarine than you get sitting in this building right now from either the building contents, the stone, or the cosmic radiation.

The other thing to note about this equipment in here is that because it is designed to operate in a rigorous environment, high-pressure, high-temperature radiation, it has to be built to exacting standards. It has to be built in a rugged fashion. They are built to last. Furthermore, they are built to last the design-life of the ship.

So when we put it in there, we expect it to stay. And that speaks to the discussion that Secretary Etter had about the initial premium of costs. We do have to ensure that those components are high quality and constructed correctly and maintained over the life of the ship to make sure that they will last for the life of that ship, and sustain in a safe and effective way, the operation of the ship.

Finally, in the sense that they do, we do design them to last for a long time. This is to show you that this model that we have had, it still works, from 1951.

Thank you very much.

Mr. TAYLOR. Thank you, sir.

Admiral, do you wish to continue?

Admiral DONALD. Yes, sir. I do have an opening statement.

Again, sir, thank you very much for the opportunity to be here. And thank you to your committee, Ranking Member Bartlett and Mr. Larsen. Thank you very much. Thank you for your support over the years of the program. Without that support, we would not have been as successful as we have been.

The naval nuclear propulsion program began in 1948 under the leadership of then-Captain Hyman G. Rickover. Admiral Rickover saw his vision come to reality on January 17, 1955 when the USS Nautilus steamed out of New London, Connecticut, under way on nuclear power.

He continued on to revolutionize maritime power plants for cruisers, aircraft carriers, and deep-diving submersibles. The virtually limitless power, endurance and flexibility afforded by these plants revolutionized naval warfare by providing the capability of sustainable persistent combat power to quickly respond where needed around the globe.

Today, as the fourth successor to Admiral Rickover, I am responsible for all aspects of naval nuclear propulsion. I fulfill these responsibilities through the leadership and oversight of the network of dedicated laboratories and training facilities, plus the nuclear-capable shipyards, equipment contractors, and suppliers that comprise the nuclear industrial base.

As the director of naval reactors, I oversee and support 103 reactor plants in 81 nuclear-powered ships, submarine NR–1, and four training and test reactors. Since 1955, we have operated for more than 5,800 reactor years and steamed over 136 million miles. Our nuclear-powered warships have safely operated for more than half-a-century without a reactor accident or any release of radioactivity that had an adverse effect on human health or the quality of the environment.

Because of our record of safe operation, our ships have virtually unimpeded access throughout the maritime domain. For example, in addition to the full freedom of maneuver on the high seas, U.S. nuclear-powered warships are welcome today in over 150 ports in more than 50 countries worldwide, thus allowing our warships to carry out their mission without constraint.

Over our history, we have built and operated nine nuclear-powered cruisers, 10 nuclear-powered aircraft carriers, and nearly 200 nuclear-powered submarines. Every propulsion plant designed, fully met, or exceeded the warfighters' requirements. Today, as ship designs advance to incorporate capabilities and warfighting needs that require more sustained energy in addition to the need for prompt global response and endurance, nuclear propulsion becomes an increasingly viable design option and should be considered for incorporation where the requirements dictate.

The formal advantages of nuclear propulsion do come with some unique costs. It must be considered in design trade studies. However, these costs are often mischaracterized. When comparing life-cycle costs, the nuclear propulsion premium, the additional cost associated with a nuclear-powered warship, and that depends on the operational tempo, the service life and mission requirements of the ship, varies between zero and 40 percent. Larger ships demanding higher energy levels have smaller premiums. Studies conducted by the Navy in fiscal year 2006 indicate that the resulting up-front acquisition premium averages between $600 million and $700 million per ship.

I would like to elaborate briefly on what that premium buys. Nuclear propulsion plant construction requires unique skills, infrastructure, and Administration to ensure that the high standards essential to safety and effectiveness are built into each component and into the finished integrated product. The plants are built to last for the design life of the ship. In the case of aircraft carriers, that is 50 years.

So the quality, ruggedness and redundancy essential to successful combat operation must be built in up-front and built to last. Additionally, this up-front cost includes paying for the full service life of fuel for submarines and half of the fuel for the life of the aircraft carrier.

Today, there are two authorized and experienced nuclear construction shipyards which have been in this business since the early days of the program. They are currently operating below their capacity. Likewise, the nuclear component industrial base is also working below its capacity. Consequently, the cost of infrastructure and intellectual capital needed to construct nuclear-powered warships, or the overhead, is borne by far fewer production units or ships than is optimal in a cost-savings sense.

The safe and effective operation of naval nuclear propulsion plants is further dependent on highly trained and competent people, our sailors. Given the plans for future capital ships that include more technology and smaller crews, I expect the same to be true in areas outside the propulsion plant in future ships.

The cost of sustaining this fine cadre of professionals is accounted for in the total life-cycle cost calculation that will be evaluated against other potential alternatives. We continue to meet our goals for both recruiting and retaining high-quality professional sailors into the foreseeable future. My training pipeline does have the capacity without further infrastructure investment to produce the additional personnel required by future classes of ships.

We must also ensure that our nuclear-powered warships are maintained at a high standard of material readiness. Over the years, we have continually evaluated our maintenance requirements and continually improved the reliability of our equipment, with the objective of only doing the maintenance necessary to ensure the safety and effectiveness of the ship.

For example, the *Ford* Class aircraft carrier propulsion plant is designed to have a 30 percent reduction in required maintenance. Not only will this reduce maintenance costs, but these gains will also provide enhanced operational flexibility. When the proper maintenance is done throughout the life of the ship, a nuclear-powered warship's availability is equal to or better than the fossil fuel counterparts. Maintenance costs are also included in life-cycle costs.

Finally, I am responsible for the ultimate disposal of a nuclear plant at the end of the ship's life. We have been doing that successfully for 20 years. We know how to do it. The technical procedures are well documented and well understood. That is also included in the life-cycle costs.

When making propulsion plant design decisions for new classes of warships, these cost factors must be considered and balanced against operational advantages associated with costs and availability of other fuel sources and with the mission requirements of the ship.

The naval nuclear propulsion program has long provided safe and reliable plants for naval warships where appropriate from a mission need and affordability standpoint. The Navy and Department of Defense have processes in place to ensure that nuclear propulsion is adequately considered in a fact-based analysis of alternatives regarding the type of propulsion plant best for warships.

My program will continue to play a key role in that process, and I will be actively involved.

Thank you very much for allowing me to address the committee.

[The prepared statement of Admiral Donald can be found in the Appendix on page 40.]

Mr. TAYLOR. Thank you, Admiral.

I am going to yield to my ranking member, Mr. Bartlett.

Mr. BARTLETT. Thank you very much.

I have a question relative to life-cycle costs. If it were possible to make a nuclear Humvee, and we can't do that yet, but if it were possible to make a nuclear Humvee, and we were trading off the cost of making this nuclear Humvee with the present diesel Humvee, I have a question about what cost factors would we put on the diesel fuel.

Presently, crude oil is about $60 a barrel, and diesel fuel is $2.59 or $2.60 or something a gallon. But I am told that by the time we get that gallon of fuel in the Humvee in Iraq, that it costs us $400. I am also told that 70 percent of all the tonnage that we move to the war front is fuel.

I wonder what fuel costs we consider when looking at fuel costs for the ship. The cost of the crude oil may be a relatively small part of the cost of getting that fuel in the ship over there. How did we account for this in our evaluation?

Secretary ETTER. I would like to ask Admiral Sullivan to address that, as the Commander of Naval Sea Systems Command (NAVSEA).

Admiral SULLIVAN. Yes, ma'am.

Mr. Chairman, good afternoon. Mr. Bartlett.

The costs of refining, storing, and transporting and testing that fuel oil was fully burdened in the study. In fact, when added to the cost, we started with about $75 per barrel, $74.15 per barrel, and the fully burdened cost of storing, transporting and getting the oil out to the ship is about $152 to $153 per barrel. So that was accounted for in the study, sir.

Mr. BARTLETT. Was there any attempt to put a value on the fact that we had freed ourselves from the necessity of fueling our ships? How do you put a value on that?

Admiral SULLIVAN. Sir, in the study, we compared the nuclear variance of the ships and we had 23 ships, as you know, in the study. We compared the operational flexibility of those ships to the operational flexibility of the fossil fuel variance in terms of surge ability, ability to move quickly from one theater to another at high speed, and in terms of time on station. In all three of those areas, the nuclear ships came out better.

Mr. BARTLETT. But you did not put a dollar value on that when you were comparing?

Admiral SULLIVAN. No, sir.

Mr. BARTLETT. I am reminded of that ad. It was not a very good ad because I can't tell you what they were selling, but the ad goes through, you know, so much for this, so much for that, and so much for the other thing, but for this it is priceless. They failed because I don't remember what they were selling, and that is the real point of an ad, isn't it? That is a technique they use. What were they selling, by the way?

Admiral SULLIVAN. MasterCard.

Mr. BARTLETT. MasterCard, all right. Selling MasterCard. Okay. [Laughter.]

It is that way, I think, with the diesel-powered ship. I don't know how you put a price that is pretty priceless to be out there, never have to go into port, never have to refuel, never worry about how far you can go and how fast you can go because you can do anything you wish.

If the Admiral would indulge me, I would just like to note another consideration. About seven weeks ago, I guess, I came back from China. One of my colleagues here was with us in China and he will certify that what I am saying is true. I don't know if he was stunned, because he is a lot more knowledgeable on China than I was, but I was stunned when they began their discussion of energy by talking about post-oil. I think essentially every one of them did it.

We first talked to some of the energy people, and they talked about their five-point program that started out with conservation. The second and third, I forget which was second and which was third, was get as much of your energy as you can at home, and diversify as much as you can so you are not dependent on any one source.

The fourth one really was interesting: Be kind to the environment. They are the least kind of any country to the environment, and they were very apologetic for that.

They noted they have 1.3 billion people, and their highest priority—and I am not sure it is all altruistic—but their highest priority is to make sure their people are content. If they aren't content, maybe there will be some political problems. And they apologized for the fact that they weren't doing well environmentally, and they actually asked for help.

The fifth one was particularly impressive. It was international cooperation. I would be happy if we had such an enlightened dialogue with leaders in our country. They seem to get it. China is doing two things simultaneously that give me some pause. One is they are going around the world and buying oil wherever they can.

You might ask, why would you do that when in today's world it doesn't matter one bit who owns the oil? Which is why I didn't go ape when the Chinese company was about to buy Unocal because it really doesn't matter who owns the oil. Whoever has the dollars can buy the oil.

So why, then, is China going around the world buying all this oil? I was told it was perhaps because they didn't understand the marketplace, but it is hard for me to believe a country that is growing at 11.4 percent doesn't understand the marketplace. Simultaneously with that, they are also aggressively building, as you know, a blue water navy. We have launched, I think, one submarine last year. I was told they launched 14 submarines last year. Now, theirs are not ours, but 14 is 14. And they are very aggressively building a blue water navy.

Do you think the day may come when they tell the world, "Gee, we are sorry, guys, but we have 1.3 billion people and it is our oil and we are not going to share it"? And you would need a pretty big navy to make that happen, wouldn't you?

I think that we need to look down the road, and although something may not be cost-effective today, I think there are enormous national security reasons for pursuing nuclear on a very broad scale across our Navy. What say you?

Admiral GREENERT. Mr. Bartlett, I would say I would agree with you that clearly we need to take nuclear power and alternative energy seriously as we look forward and evaluate our classes of ships. We are doing exactly that in our analysis of alternatives. We will continue to do so.

Mr. BARTLETT. They are ringing the bells, Mr. Chairman. I know you have a number of questions. I really appreciate your enthusiasm for looking at nuclear in our Navy. I would hope that we would look beyond just the dollars.

By the way, before I yield, I would like to note that in the kind of rough-cut study you did some time back, you had exactly a reversal of what it would cost. You had the large-deck amphibs as being competitive at, what, about $70 or $80 a barrel, and you had the other ships as being, so we have an exact flip this time. It is kind of interesting.

Admiral DONALD. Sir, I can talk to that, because the quick-look study, the original one that was done was one that we worked with NAVSEA to develop. What is different about that study and this one is that we took into consideration the operating profiles of the ships. In ours, it was really more a displacement versus cost of oil and the amount of time—a relatively basic operating profile.

We got more sophisticated, I would say, in the study that was recently completed because it took into account mission requirements, operating profiles, a variety of those operating profiles, whether it be high speed, or whatever it turns out to be. Admiral Sullivan can address those more specifically.

Also, what was different between this study and the one that you saw the first time, is it took into account the electric energy requirements, the energy requirements on the ships for maybe advance sensors, whether they be radars. And that turned out to be a decisive point. I would let Admiral Sullivan discuss that further, if you should desire any more.

Mr. BARTLETT. I can understand how that would make nuclear more competitive for the combatants, but I don't understand why it changed the dynamic for the large-deck amphibs.

Admiral DONALD. Sure.

Admiral Sullivan, do you want to speak?

Admiral SULLIVAN. Yes, sir.

The reason the large-deck amphib became less competitive for a nuclear power plant is that we modeled a specific propulsion configuration baseline that we now have in building in the LHD–8 class, where that ship has a diesel engine running a small generator that generates about 5,000 horsepower. You can run the ship around on that generator on the diesel engine for 85 to 90 percent of the time it is in service. That is a very, very efficient power plant. So when compared to that power plant baseline, nuclear power became less competitive.

I would like to add, though, that even in the amphibious ships in the study, on a procurement cost basis, they were definitely more expensive. The life-cycle penalty on those ships was only seven percent to eight percent, when you compared over the life-cycle of the ships. So it is not a big delta.

Mr. BARTLETT. Thank you, Mr. Chairman.

Mr. TAYLOR. Thank you.

I would like to announce to all the members that we are going to have, I believe, five votes, and probably going to gobble up about one hour. So we are going to try to back out where we can now. I would encourage those of you who can return to return.

I would also like to announce that because this room is going to be used for another briefing that we will be resuming in 2116, so you will have about one hour to eat lunch or whatever.

Mr. Larsen.

Mr. LARSEN. It seems to me we are going to have to, next time we will have you scheduled at a different time. As I recall, the last time you all were up here we had votes as well. We can't control that and we apologize as well.

I apologize, my questions may be basic. This is a little bit new to me.

For Admiral Donald, I was wondering about the scalability. From a submarine fleet to carriers, I imagine there is a difference in scale. And then what it takes to scale, presumably something in the middle. Is this closer to the submarine-size system or a carrier-size system, or surface ships?

Admiral DONALD. Sure. Yes, sir. The design of the propulsion plant follows the design, or is conduced in conjunction with the design of the ship itself. You have to size the power plant to meet the needs of the ship. That calls for different capabilities, different megawattages, different shaft horsepowers.

What we looked at when we worked with Admiral Sullivan in the study for a mid-size surface combatant for the purposes of the study, we looked at a power plant that is about half the size of the one that we would be putting into the next generation of aircraft carriers, the *Ford* Class aircraft carrier. That is typically a two-reactor ship. We would look at using a one-reactor ship. That is the design we followed.

It would probably take some modification in some of the electrical generating equipment based on the type of propulsion train you would put in, but that was generally about the right size for what we considered, and provided some margin for growth in the future of the ship, since these ships are typically designed to last for 30 years or so. That was basically what we did.

Again, once you get into the details of the construction and design of the ship, you would have to size it appropriately. We believe that we have technology, certainly, and components that are in the rough size to be able to make a good estimate.

Mr. LARSEN. Okay. The Chief of Naval Operations (CNO) was here earlier today to talk about the budget. A variety of issues came up, including the CGX. This gets to the question of the timing. If there is a fish-or-cut-bait time coming, what is that time for you all to say we are going to use this kind of system, or we are going to stick with the traditional diesel?

Admiral DONALD. Given the timelines in the Navy shipbuilding plan, it would start into the preliminary design in 2011, construction in 2013. We, the nuclear propulsion business, would typically be on-point because we need to get our components, the heavy components like the reactor vessels, as you see, and those types of equipment, the core itself, under construction quickly.

Assuming that you would use an existing plant with minor reconfiguration needed, we would need to get our heavy equipment on order about four years prior to the start of construction.

Mr. LARSEN. About four years prior to 2011?

Admiral DONALD. Prior to 2013.

Mr. LARSEN. So two years from today.

Admiral DONALD. Approximately four years prior to construction. Again, assuming you wouldn't want to be doing a lot of redesign to be able to achieve that type of timeline. I think we have to understand what the ship is going to look like, because we haven't gotten into that in any detail yet. There are certainly other areas of ship design that would have to be considered that would probably result in it being as limiting as anything I would have as far as design of the propulsion plant is concerned.

Mr. LARSEN. So whatever the ship design is, you need about two years lead time. It is not just a matter of flipping a switch and we are ready to go. You need about two years lead time to craft your nuclear propulsion system for the ship that is designed.

Admiral DONALD. Prior to start of construction, again back up approximately four years, and while, again assuming that I can use existing components with minor redesign, I can get those on order and then the arrangement work can be going on simultaneously.

Mr. LARSEN. Okay, okay. Just a quick question. Obviously, in Washington State, we have a historical problem with nuclear waste disposal. It is a very difficult challenge for us, that we continue to pay for. I think we are on top of that, but that is another subcommittee. Can you answer the question for us, because this may be common knowledge, I don't know: How do we dispose of the facilities when we decommission?

Admiral DONALD. When we inactivate a nuclear ship, it is a multi-step process. The first thing that we do is we remove the fuel from the ship, because we don't allow ships to sit around idle with fuel still in them. We do remove the fuel. That fuel is shipped to Idaho, near Idaho Falls at the naval reactors facility which is at the Idaho National Laboratory.

We then use that facility to examine all of our fuel post-use. That is how we have been able to extend the lifetime of cores through that examination, and learning from our designs, and improving on it. Once the examinations are complete, we are now moving the fuel out of water pits, which is where it is right now, and moving it into what we call dry storage.

It is essentially moving the fuel out of the water pits configured in a way for long-term dry storage into large canisters, about 350,000 pounds apiece. Those canisters are now road-ready, we call it—ready to go to the ultimate land depository, if it is Yucca Mountain or wherever it turns out to be. We are in a position to move that. It would remain in dry storage in that facility until the shipment is actually started. We are in production now to move that fuel. It is going into dry storage as we speak.

Mr. LARSEN. One final question: Are those vitrified or is it just the core and it is stored in a canister?

Admiral DONALD. No, it is actually components of the core. The fuel rods themselves are disassembled as a part of the process, and then they are stored in a specially designed container to maintain the integrity of the equipment and maintain it in a safe condition for as long as it would be in storage.

Mr. LARSEN. Yes. Thank you.

Admiral DONALD. Yes, sir.

Mr. LARSEN. Thank you, Mr. Chairman.

Mr. TAYLOR. Thank you, Mr. Larsen.

The committee will stand in recess until 4 p.m., at which time we will reconvene in 2116. Thank you very much. I am sorry for the inconvenience to all of you.

[Recess.]

Mr. TAYLOR. Again, we apologize for the delay. Thank you for sticking around.

The chair now recognizes Ms. Gillibrand.

Mrs. GILLIBRAND. Thank you so much for coming.

I started to have a conversation with the admiral just for a second. My district is in upstate New York. We have a nuclear facility there, the Knolls Lab.

I wanted to know, with the Navy's current planning, how will production be impacted in our lab? Is there any way that we can facilitate any of the work that you plan to do?

Admiral DONALD. We had started to talk about that concept that was used in the study that was done by Admiral Sullivan. I assume that we will be using an existing design to the greatest extent possible. The degree to which we can do that depends on what the ship configuration looks like and what the energy needs are for the ship. But ideally, we like to use existing components.

Along with that would have to be some reconfiguration, as opposed to a major redesign. So in that sense the intellectual capital and the resources that we have in our labs right now is sufficient to deal with that.

If you do talk about a long-term expansion and a new class, a larger class of ships over a longer period of time, then obviously you have to look at what the resources are like in the lab to be able to support the fleet support on a day-to-day-type technical support that would have to go into that, but that would be what we would consider.

Mrs. GILLIBRAND. And do you see any other applications for the technologies that are being developed in the lab now, to see it being able to be used for civilian use or commercial use down the line?

Admiral DONALD. We frequently get asked for other applications for the reactors that we build. One of the things that we have to consider is that the plants that we build are designed for a very specific circumstance, that is a naval vessel. With that comes a requirement to be combat ready, to withstand combat shock-loading and things of that sort.

We tend to build things into our plants that for a commercial application, that were doing it for profit, you wouldn't do that. It is not the type of thing that you would do. This really would be a gross over-design for something like that. So in that sense, the product that we build is unique to what you would use in the military and our naval application, and not necessarily have a civilian application.

Mrs. GILLIBRAND. Thank you.

Are there any improvements or investments to the Knolls Lab facility that you would like to see? Is there anything that you think needs to be upgraded or updated within the facilities as they exist now?

Admiral DONALD. First off, I would love to have the opportunity to host you at the Knolls Lab and come visit and see the place. If you look at our budget plan for 2008, it has the requirements that we need for the next fiscal year to sustain the lab and do the improvements that we need to make to sustain the program for the long haul.

We have obviously got long-term plans that we are working with, and we will address those in the budget years. But right now, you have taken very good care of my program and we have been able to support the fleet accordingly. Thank you.

Mrs. GILLIBRAND. Thank you, Admiral.

Admiral DONALD. Yes, ma'am.

Mr. TAYLOR. I thank the gentlewoman.

Admiral Donald, one of my frustrations as a representative of the citizens, trying to see to it that the tax dollars are used to the best, is a trend to retire ships well before their 30-year life expectancy. We never really get to the size fleet we want.

I am curious. In your professional opinion, would a nuclear cruiser be more likely or less likely to have all the power onboard it is going to need for that 30-year life of the ship, keeping in mind that some people think the future of naval weapons is going to be directed energy, and that that is going to require an enormous amount of power when that program and platform is onboard, and hopefully sooner than later.

Admiral DONALD. Yes, sir. One point, I would just like to revert back to the hearing earlier today. I want to correct a statement that I made that may at least have confused people. When I talked about the construction start, the contract start for the next cruiser, I indicated that 2013 would be when I would need to have my components ready to start.

The implication could be that that implied authorization in 2013. The authorization is 2011, as indicated in the CNO shipbuilding plan. I just want to make sure I didn't confuse anybody, other than myself, when I said that.

To your question specifically——

Mr. TAYLOR. So for clarification, back up before your long lead time, you are talking about you need a statement of intent either coming from within the Navy or coming from the Congress this year or next, right?

Admiral DONALD. No, sir. Again, it remains the same for me. The point in time in the construction of the ship, from an authorization at the level of what I would need to have my components landing and commencing assembly in the yard, would be about the 2013 timeframe.

So I have to back up approximately four years from that to be able to be ready to do that, so you are talking obviously the 2009 timeframe that I have to start getting heavy components under order and a government furnished equipment (GFE) for the nuclear plant under order and construction.

Mr. TAYLOR. In your testimony, at least in the testimony as I read it, you mentioned a possible cost reduction because of economies of scale when it came to nuclear power plants for the *Virginia* class and other classes.

What do you think that would translate to, given that when you compile all of the things that are possibly in play now, which would be authorizing a second and appropriating a second submarine this year, if we were, as a Congress, to mandate nuclear cruisers? Would that be part of the game plan?

Realistically, what kind of cost stabilization or what kind of cost savings do you think we could achieve by doing both of those things?

Admiral DONALD. First off, let me take the *Virginia* class first. The analysis that we have done on going to two-per-year of *Virginia* would result in an approximate savings per hull of about $200 million. There is some additional savings that you could probably gain through the work, or you would gain, in fact, through the work that we are doing as a part of the challenge the CNO gave us on reducing the overall price of the ship to $2 billion. But just based on the volume and the improvement in economic order quantities, we estimate about $200 million per hull.

If you lay in now consideration for a cruiser, then first off, there would be an impact in the industry, an immediate impact because once you start ordering components, then you can start dissipating overhead in these organizations, these vendors that I have, very quickly to dissipate the overhead and drive down the unit price of the components.

I have rough estimates, if you were talking about over a class of cruisers and getting one every two years, in the end-state you would be talking about something on the order of about seven percent reduction in the price of the GFE that we provide to the ships—about seven percent.

For an aircraft carrier, it is something on the order of about $115 million a set. For a submarine, it is something on the order of about $35 million per set of GFE, but that is in a steady-state environment over a series build of ships. So that is probably the most optimistic estimate that I would give you, but that you would get some savings certainly in economic order quantity, and in being able to spread the overhead out over a larger base.

Mr. TAYLOR. Okay. So playing devil's advocate, we are not going to hear from the other side that, well, you are taxing the industrial base and we are going to pay a premium for this if we order too many nuclear-powered vessels. Is that accurate? Do you foresee a circumstance that the industrial base comes back to us and says you are now ordering too many of these things; you have to pay a premium? Or do we end up getting economic order quantity?

Admiral DONALD. Right now, as I look across the industrial base that provides, let's just talk about the components, for instance, and I just look across that base, because we have been asserting earlier that we were going to go to two-per-year *Virginias*. We had facilitized and have sustained an over-capacity in those facilities to support construction of those additional components.

So right now, it depends on the vendor and which one is doing what, the capacity is running right now at probably about 65 percent of what it could be doing, on the order of that. Again, it varies depending on the vendor specifically.

So there is additional capacity in there, and even with the addition of a second *Virginia* class submarine, there is still a margin in there, if you are talking about a single cruiser in the early phases of design, we still have margin in there that I believe we can sustain that work in addition to the submarine work within the industrial base.

We would have to look at that in more detail once we determine what the design looks like and the degree to which we can use existing components. If you had to design new components, that would add a little bit more complexity to it, but that is a rough estimate of what I would provide for you now.

Mr. TAYLOR. I believe the secretary had in her testimony, and made reference that we have two nuclear-certified yards at this time.

Admiral DONALD. Right.

Mr. TAYLOR. Keeping in mind that we have five surface-combatant shipyards, or capable shipyards at this moment. To what extent could the other three participate in bidding on these? To what extent could a very large portion of the hull be built, and then towed to either one of the two nuclear yards for the nuclear components? How expensive is it for a yard that is not at the moment nuclear-certified to become nuclear-certified? How big a hurdle is that?

Admiral DONALD. I think it may be best to split that question in two pieces. I will cover the latter piece, the discussion of——

Mr. TAYLOR. How would you do it ideally?

Admiral DONALD. I am sorry?

Mr. TAYLOR. And the third part would be, under ideal circumstances, how would you see this taking place?

Admiral DONALD. I will go ahead and address the piece of that about what it takes to certify and to re-establish or establish another nuclear-capability yard, and then I will ask that Secretary Etter and probably Admiral Sullivan discuss the second piece of it.

Just the basics of what it takes to have a nuclear-certified yard, to build one from scratch, or even if one existed once upon a time as it did at Pasacagoula, and we shut it down, first and foremost you have to have the facilities to do that. What that includes, and I have just some notes here, but such things as you have to have the docks and the dry-docks and the pier capability to support nuclear ships, whatever that would entail.

You would have to have lifting and handling equipment, cranes, that type of thing; construction facilities to build the special nuclear components, and to store those components and protect them in the way that would be required. The construction facilities would be necessary for handling fuel and doing the fueling operations that would be necessary on the ship—those types of things.

And then the second piece is, and probably the harder piece other than just kind of the brick-and-mortar type, is building the structures, the organizations in place to do that work, for instance, nuclear testing, specialized nuclear engineering, nuclear production work.

If you look, for instance, at Northrop Grumman Newport News, right now, just to give you a perspective of the people you are talking about in those departments, it is on the order of 769 people in nuclear engineering; 308 people in the major lines of control department; 225 in nuclear quality assurance; and then almost 2,500 people who do nuclear production work. So all of those would have to be, you would have to find that workforce, certify and qualify them, to be able to do that. And then finally you have to train them, obviously, and then qualify them to do the work.

So my view of this is we have some additional capacity at both Electric Boat and at Northrop Grumman Newport News. My primary concern is if we are serious about building another nuclear-powered warship, a new class of warship, cost is obviously going to be some degree of concern, and certainly this additional cost, which would be—and I don't have a number to give you right now, but I think you can see it would be substantial to do it even if you could. It probably doesn't help our case to move down the path toward building another nuclear-powered case, when we have the capability existing already in those existing yards.

And then I would turn it over to Secretary Etter or Admiral Sullivan, whoever wants to take that next piece of it.

Secretary ETTER. I think this is really an Admiral Sullivan question.

Admiral SULLIVAN. Sir, we are building warships in modular sections now. So if we were going to, could you assemble this, could you build modules of this ship in different yards and put it together in a nuclear-certified yard, the answer is yes, definitely, and we do that today with the *Virginia* Class. As you know, we are barging modules of submarines up and down the coast.

What I would want is, and sort of following along with what Admiral Donald said, you would want the delivering yard to be the yard where the reactor plant was built, tooled, and tested, because they have the expertise to run through all of that nuclear work and test and certify the ship and take it out on sea trials.

But the modules of the non-reactor plant, which is the rest of the ship, could be built theoretically at other yards and barged or transported in other fashion to the delivering shipyard. If I had to do it ideally, that is where I would probably start talking to my industry partners, because although we have six shipyards, it is really two corporations, and those two corporations each own what is now a surface combatant shipyard and they each own a nuclear-capable shipyard.

I would say if we were going to go do this, we would sit down with them and say, you know, from a corporation standpoint, what would be the best work flow? What would be the best place to construct modules? And how would you do the final assembly and testing of a nuclear-powered warship?

Mr. TAYLOR. Okay.

The chair yields to Mr. Sestak.

Mr. SESTAK. Thanks, Mr. Chairman.

I am sorry I was late. I think probably most of these questions have been asked, but I am a slow learner, so if you don't mind.

A question I had was about the steaming hours that you used in your study, from going through it, it looked like you based it upon historical, looking back at fiscal year 2001 through 2004, or something like that. Why didn't you just use the steaming hours that you planned for, you know, the 51 or the 22?

Secretary ETTER. I think Admiral McCullough might be able to address that, or is that Admiral Sullivan, too? Okay.

Admiral SULLIVAN. What we really did, and that is a great question because historically we didn't do a very good job of understanding the operating profile and the total energy requirements of the ship. So what we did, yes, we took that history for the small combatant and medium combatant and amphibious ship, based on the last, it was probably ten years.

But we also said, okay, let's talk about the prediction for looking at the mission suites of similar ships, predicting into the future, using the operational analysis that worked up to the 313-ship Navy, looked ahead and bounded the problem by having a high operating profile, a medium operating profile and a low operating profile.

And then, really, the reason we looked at the history was as a check to make sure we were not out of bounds with our high, low and medium operating profiles. So that produced a range of break-even analyses, which gives you the range that we have given you.

Mr. SESTAK. But when you came back and you said the high operational tempo was probably unlikely, and you kind of came back and said it is probably more about the $115 one. It looked to me as though your analysis for that one was based upon what history was, somewhere between the lower operating profile and the medium one. It was hard to discern it, but it seemed to me you were trying to say we based it on historical patterns, those two, and that is the more likely. Is that right?

Admiral SULLIVAN. No, sir. We actually went ahead, it is budgeted, but for the emissions suite analysis of similar type ships and looked ahead at those sorts of operating profiles.

Mr. SESTAK. The only reason is that the Navy has gone down in its funding on the one hand. Instead of 22 days at home, 28 days under way, 22 days at home, it has come in with a budget last year saying 36 days under way per quarter for four deployed forces. As a matter of fact, this year they upped it some to 40-some.

So I didn't know whether, you know, we should be using what the Navy, as we go forward in this analysis, should we be using what we are going to be funding for? I mean, does that help any?

Admiral SULLIVAN. I would tend to think that Barry ought to take this question. I will tell you that the reason that you look at history is it varies a lot. There are some years when we don't do a whole lot of steaming. There are some years where there is budget constraint, and there are other years where if you looked at that profile, 2003 was way up there because we went to war. We took the whole fleet and steamed. I think 75 percent of the fleet was forward-deployed much of that year.

So the good thing about the history is that it smooths, if you take it over the long haul, and these ships are 30- to 50-year service life, depending on which kind of ship you are talking about, you tend to average out those that you budget for in a 5-year cycle. Beyond that, I ought to turn it over to Barry.

Admiral MCCULLOUGH. Yes, sir. If you look at our typical operating patterns in home port, even though we are funding initially to 28 days-a-quarter under way, we found that we were really only using about 22 or 22–1/2 of those days. So I would tell you that home port or in Continental United States (CONUS) steaming days that we funded in the budget at 22 is about right.

When you look at what we do deployed overseas, it is in excess of what we put in the budget. But when we balanced all the requirements we had across the spectrum of our portfolio, we believed that 45 days was about acceptable with risk.

Mr. SESTAK. Again, this, as well as energy requirements, are the two strong drivers. Correct? At least for this portion of the study, for cost?

Admiral MCCULLOUGH. Yes, sir.

Admiral SULLIVAN. Yes, sir.

Mr. SESTAK. So it really does matter where that variable comes from, I gather.

Admiral SULLIVAN. But if you are within the lower limit, that is something you ought to look at. That means you ought to be considering nuclear power for the ship. We didn't say that if it looks like the lower limit, you shouldn't, because most of the range of price of oil was above that limit. If it is close to the lower limit, you should look at that.

Mr. SESTAK. The radar requirement, I gather, for Theater Ballistic Missile Defense (TBMD) is about 31 megawatts?

Admiral MCCULLOUGH. Yes. If you look at the energy requirements in the spectrum of sensitivity radar we are looking at, it is around 30 megawatts.

Mr. SESTAK. About 30?

Admiral MCCULLOUGH. Plus or minus.

Mr. SESTAK. About 30 or 31. And that is the other big driver in this, correct?

Admiral MCCULLOUGH. Yes, sir. If you look at our requirements for this particular ship, it is on the order of 30 megawatts. If historically you look at *Aegis* ships and you run an *Aegis* combat system, it is about five megawatts to run the combat system and ship service load in a combat condition.

Mr. SESTAK. Admiral, isn't there some real efforts in order to, as you look at CGX, and I know I am getting into worlds that you can't get into, but isn't there a real effort to draw down, push down that power requirement for CGX?

Admiral MCCULLOUGH. Sir, as you noted, the sensitivity equation and the proportionality is based on aperture size, and power is a cubic. So if you can get more area in the aperture, you can drive the power requirements down, and we are trying to balance that. Yes, sir, that is true.

Mr. SESTAK. So 31 may be a variable right now?

Admiral MCCULLOUGH. The 31 is the power requirement, ship service distribution.

Mr. SESTAK. Based on how we do things today, not about how we are trying to change CGX TBMD radar, is that right? Or would that be unfair to say that there are efforts to——

Admiral MCCULLOUGH. I will let Admiral Sullivan take that piece of it.

Admiral SULLIVAN. As Barry said, it is all about aperture and power. What is available today takes a lot of power and takes a lot of cooling. So the 31 megawatts, that is about the requirement that we had in our medium surface combatant. You would like to, obviously, reduce that power draw, and there are several development programs out there to in fact take the power requirement down.

However, that is going to be a risk balancing. Do you take the aggressive technology that takes the power out, and maybe costs a lot more money, or maybe doesn't come true when you need it in the timeline of this ship? Or do you take the less aggressive power reduction and have it be something you can bet on, put the generating capacity in the ship, and then go off and design the ship? On a timeline of this ship design, the radar may be the pacing requirement.

Mr. SESTAK. I believe the radar is the pacing requirement, right? It is also a driver, one of the two main drivers for this. And so whichever way you do go is going to be a determinant in this study, right?

Admiral SULLIVAN. Yes, sir.

Mr. SESTAK. The other issue, and I am not sure how pertinent it is, because obviously, like our DDGs that we might set off in the Sea of Japan, the three, well, I don't know how many are out there now, but you know the three I am talking about.

Admiral SULLIVAN. Yes, sir.

Mr. SESTAK. If they are just going to sit around out there to do that mission, something like nuclear power can be attractive. My question, though, is as you watch the Iranians, and I saw your survivability, you know, what you put down for the other major issue, survivability, that there are a number of other means that can help enhance the survivability of a ship.

When we watch the Iranians, apparently the Iranians are supplying these explosively formed penetrators (EFP), which even our best armor doesn't seem to be able to protect against. Is this a concern for a nuclear-powered ship as you have them out there?

Admiral SULLIVAN. EFPs are a concern, as are many, many other terrorist threats to all our ships. We have researched that well. We know that the effects are. I would be happy to discuss them in a classified session if you want.

Mr. SESTAK. And the other thing, this reactor is a nondevelopmental reactor, correct?

Admiral DONALD. That is correct. The study that was done, what we assumed, and it was about the approximate fit given what we understood, what the assumptions were for the power learning. It is the exact same reactor that we are designing and constructing right now to go into the *Ford* class aircraft carrier.

Mr. SESTAK. So there is no re-coring? Or is there a re-coring requirement?

Admiral DONALD. There is.

Mr. SESTAK. Is that cost in this?

Admiral DONALD. It is. That is in there.

Mr. SESTAK. It ought to be in there.

Admiral DONALD. That is in the life-cycle costs. Right.

Mr. SESTAK. That is in it. So you have already, Admiral, included that in here?

Admiral DONALD. That is correct. I think that is correct.

Mr. SESTAK. I couldn't find it in the study.

Admiral DONALD. For the carrier, it is a mid-life refueling. For the cruiser, it is a life-of-the-ship.

Mr. SESTAK. So it is for the life of the ship?

Admiral DONALD. It is.

Mr. SESTAK. That is what I thought it said.

Admiral DONALD. Yes.

Mr. SESTAK. So there is no re-coring requirement?

Admiral DONALD. Correct.

Mr. SESTAK. How many years will it give?

Admiral DONALD. Thirty years, approximately 30 years.

Mr. SESTAK. So the non-recurring costs are not in here, the non-recurring?

Admiral DONALD. That is correct. The non-recurring costs associated with the design work that would be needed to reconfigure the existing components is not included in the calculation. That is right.

Mr. SESTAK. Would that include the disposition of the material after we are done with the life of the ship?

Admiral DONALD. Yes, sir. It does. That is incorporated. The ultimate disposal of the fuel and the reactor components is included in the life-cycle cost.

Mr. SESTAK. It is included in the life-cycle costs?

Admiral DONALD. Yes, sir.

Mr. SESTAK. I am sorry. I just jotted down, and it looks as though it is only a ten percent impact, Admirals, for the training of the manpower. In other words, in your pipeline. Admiral, I guess this is yours, the training for nuclear-powered?

Admiral DONALD. Right.

Mr. SESTAK. The impact on the additional training is not that enormous?

Admiral DONALD. No. We, in looking at the training pipeline, there are a couple of dynamics that are in work right now. First off, the *Enterprise* is going to be going away, and that is a pretty significant training load just to keep that crew operating. And also as the CVN–21 comes on, the *Ford* class carriers come on, and the *Nimitz* starts to go away, we are targeting a 50 percent reduction in the reactor department sizing over there.

So for the foreseeable future, the training infrastructure that we have right now will meet the needs to sustain this class, if you choose to do it.

Mr. SESTAK. In regards to the *Enterprise*, what is the disposition cost of the *Enterprise* going to be?

Admiral DONALD. Right now, the estimated disposition price of that is on the order of about $1.1–1.2 billion. That includes not just the nuclear piece of it, but that is the entire ship disposition cost.

Mr. SESTAK. And the very last question is, the price today that we pay for fuel is about $74. Is that what we mean by "bbl"?

Admiral SULLIVAN. The basis used for the study was $74 per barrel, and then the fully-burdened cost of storing it, testing it, transporting it out to the ships, I think I had——

Mr. SESTAK. $156 or so.

Admiral SULLIVAN. Yes, sir.

Mr. SESTAK. I see. Let me question, does that actually represent what you are paying today?

Admiral SULLIVAN. Well, today the price of oil—I checked—is about $62 a barrel.

Mr. SESTAK. I see. So today is it $62, and then it would ratchet up to probably $140, you know, for the additional costs. And that "bbl," that is just the cost of the crude oil.

Admiral SULLIVAN. It is the cost to refine, store—the fully burdened cost of what we pay to get the oil to the ship.

Mr. SESTAK. Does that include the infrastructure costs within it?

Admiral SULLIVAN. I don't think it includes the cost of the oilers, but I would have to check on that.

Mr. SESTAK. How about storage?

Admiral SULLIVAN. Yes.

Mr. SESTAK. The reason I was asking is, it seems as though that price—and I am sorry, if I can work through this, because I was a poli sci major—but that price, let's say it is $74, because I think that is what your study said, if that includes the infrastructure costs, should that be the price we use in the study? Because the infrastructure cost is going to be the same for the Navy, whether or not the price of oil goes up or down? So shouldn't we extract the cost of the infrastructure for it?

Admiral SULLIVAN. I am not sure I understand the question, because the cost we used in the study was actually the $150 burdened cost.

Mr. SESTAK. Which includes the infrastructure costs?

Admiral SULLIVAN. Yes.

Mr. SESTAK. Because this will be a small subset of ships, the CGX. I think you are planning—how many are you planning?

Admiral MCCULLOUGH. Nineteen.

Mr. SESTAK. Nineteen.

Admiral MCCULLOUGH. Yes, sir.

Mr. SESTAK. So out of the 316 ships, this infrastructure cost of $156 is going to be fixed to some cost. So shouldn't you be basing the break-even point cost on the variable cost of oil absent the cost of the infrastructure, because the infrastructure cost is going to be the same for many of the other ships?

Admiral SULLIVAN. I guess I have to take that for the record, sir.

Mr. SESTAK. But you understand what I am asking?

Admiral SULLIVAN. Yes, sir.

Mr. SESTAK. I mean, the study would come out totally different if that is a fixed infrastructure cost for the other 290-some ships.

Admiral SULLIVAN. I don't want to get out in front of going and pulling the true costs out, but I believe the incremental costs that we cost are the oil to go to the ships——

Mr. SESTAK. Could you back that? Because if it is true the fixed costs are sunk anyway, then you should only be doing it, and that would make the outcome——

But you understand the question?

Admiral SULLIVAN. Yes, sir.

Mr. SESTAK. If only I had that nuclear-trained background. [Laughter.]

Thank you very much, Mr. Chairman.

Mr. TAYLOR. Admiral McCullough, following up on Mr. Sestak's question, it is my understanding that one of the major responsibilities of the next generation of cruisers is to provide missile defense for the carriers.

Admiral MCCULLOUGH. Yes, sir. That is correct.

Mr. TAYLOR. Would that be in its top three missions?

Admiral MCCULLOUGH. Yes, sir. That is correct.

Mr. TAYLOR. And, you know, I have been amazed at how our enemies have found our weaknesses. So I have to believe that any potential rival is going to particularly know that we want to play an away game. He is going to realize that the Achilles heel of the American military is fuel.

I am told we have about five oilers in the Pacific. If I was a foe of the United States, I would find a way in my opening round to take care of those five oilers by some means. So what good is a missile defense for a nuclear-powered cruiser if it can't keep up with the carrier because it ran out of fuel?

Admiral MCCULLOUGH. Well, sir, first I would say when we build a ship of this capability, we are going to have to reevaluate the concept of operations under which we employ it. Maybe it is a mindset change from the days of when the cruiser had to run with the carrier, so the carrier operates under the umbrella of protection that the CGX provides to the sea-base.

As far as your discussion about oilers, operationally, Admiral Greenert can help me with this.

Admiral GREENERT. Yes, sir. The oiler distribution in the Pacific, there are five oilers, that is correct. But when we operate the oilers, we distribute the oilers. In other words, they would not all gather in and around the sea-base. And we also have other alternatives for a means of refueling. So my point is, if an opposing force could distribute their navy in the manner that we have our oilers distributed, that would be a threat.

But what I would offer, sir, is that it would be a very, very complex matter, one taking great scheming and many alternatives. I would submit beyond what we would foresee with anybody that we know today, that threat today, and extrapolate to 2020.

Mr. TAYLOR. Going back to the admiral's point of the explosively formed projectiles, five Boston whalers in five ports. I mean, you are not talking about distributing the Navy. You are talking about whatever rules for whatever means—rocket propelled grenades (RPGs) hitting a rudder. I don't see that as all that far-fetched.

Admiral GREENERT. Yes, sir. Using these as examples, if you will, as you look at this, one of our concepts of operation would be to keep these whalers under way and at various stations. The point being, and within the concept of operations, to not have yourself in various modes, if you will, where you are liable to that.

The way we rotate the oilers, the way we use our fueling stops beyond the oilers, because there are other opportunities in the Western Pacific other than just the oilers for fueling. We would protect them as capital ships in a threat environment, and that includes today's environment. That would be key and critical to the fleet commander's operations, to preclude the very scenario you have said where we have too many in port and vulnerable to that kind of attack.

Mr. TAYLOR. To that point, what value, if any, was given to the nuclear force plan as a means of being able to keep up with a carrier at any time, without the need for oilers? Are we removing that vulnerability of the need to refuel? Was that weighted? Going back to the admiral's questions about, did you consider your fixed costs?

Admiral SULLIVAN. Again, the cost savings of having that ship be free, the medium surface combatant in this case, which is not CGX. It is a notional ship design. It is included in the operational effectiveness study, but it is not added or subtracted as a cost of the cost of doing this. It is not part of the study.

Mr. TAYLOR. It is recognized as a good thing to have, but not included in the cost value.

Admiral SULLIVAN. Okay.

Mr. TAYLOR. The chair yields to the gentleman from South Carolina, Mr. Wilson.

Mr. WILSON. Thank you, Mr. Chairman.

I would like to thank you for your service.

In lieu of a question, I would just make a statement that I had the opportunity to grow up in Charleston, South Carolina. We were so proud in my growing up to see the *Polaris* submarines and the *Trident* submarines. I just grew up with a great appreciation of how the nuclear Navy made such an impact in protecting the American people and ultimate victory in the Cold War.

And then I have had the privilege of touring the Nuclear Power School there in Charleston two years ago. It was just awesome to see the young people being trained. They were able to receive college credits, which I was not at all aware of, and to learn a skill that indeed they will be able to carry the rest of their lives.

So I want to thank you for your service, and I look forward to working with the chairman in a way to back you up. Thank you.

Mr. TAYLOR. Thank you.

Mr. WILSON. I yield.

Mr. TAYLOR. Thank you, Mr. Wilson.

The chair yields to the ranking member.

Mr. BARTLETT. Thank you very much.

I have a couple of questions about disposal. How much of the fuel has been consumed in that 30 or 33 years?

Admiral DONALD. Typically, again it depends somewhat on the type of core and how it has been employed, but typically about half of the fuel has been consumed over the life of the ship.

Mr. BARTLETT. I was always intrigued by the challenge of something that is so hot that I have to squirrel it away for a quarter-of-a-million years and I can't get near it, that it ought to be good for something. If there is that much energy left in it, it has just got to be good for something.

Who ought to be addressing that challenge? Because in an increasingly energy-deficient world, there is going to be some interest. Who should be addressing that challenge? It has to be good for something, doesn't it?

Admiral DONALD. There is right now, the Department of Energy, that is the answer, and certainly commercial partners if they choose to get into this. But there is an initiative right now called the Global Nuclear Energy Partnership, which involves a combination of technologies, including reprocessing, taking spent fuel and reprocessing it, and recovering the nuclear material that may be of further use, and disposing it in a couple of advanced, or means of disposing it as a waste in a more probably user-friendly, environmentally friendly way than what is done typically today. But that is all advanced technology. It is a program of record. It is ongoing in the Department of Energy right now.

Today, however, if you look in the nuclear industry, and in fact, in the Naval Nuclear Propulsion Program, we used to recycle spent fuel. We would bring it in. It is a chemical process basically of dissolving the fuel and extracting the uranium that was still usable and then reusing it. One of the problems with that technology, however, at the time, it was very expensive compared to what the price of uranium was. So it was deemed to not be economically feasible.

The other problem with reprocessing, in the sense that we do it today, and certainly we did in the United States, it also generates some pretty significant waste streams over and above what you would normally have with the spent fuel. So in that sense, it didn't make much economic sense. And there were some environmental legacies that you had to be concerned about, and a decision was made that we are just not going to do that any longer.

We are in the business of doing dry storage right now. You are right. There is a resource there that it would be helpful if we could get to in an economically correct way and an environmentally satisfactory way. That is the effort that is going on right now in the Department of Energy, with their Global Nuclear Energy Partnership.

Mr. BARTLETT. Oil at $100 or so a barrel will have a way of focusing the mind, I think.

Admiral DONALD. It certainly can. Yes, sir.

Mr. BARTLETT. I was absent for a few minutes here. My apologies. The reason was that there is a Government Accountability Office (GAO) report that is out on peak oil. There are now two reports out there for a year or so. One is the big study done by Science Applications International Corporation (SAIC) for the Department of Energy, which concluded that we probably were or shortly would be at peak oil with perhaps devastating consequences. They made statements like, "the world has never faced a problem like this; the mitigation consequences will be unprecedented."

Then there is another study done by the Corps of Engineers at the request of the Army, which has concluded about the same thing. Today, there was an Associated Press (AP) article saying that T. Boone Pickens—who I didn't know until I read the article, started his career as an oil geologist—he now says that we are at peak oil.

I was walking over from the last vote with Dave Hobson. I want to pass on to you his compliment of the military. He said that you all were doing a good job with energy. You are doing about the only thing that is being done in our country relative to energy. Thank you very much.

If in fact T. Boone Pickens is right; if in fact these other studies are correct, today we are dependent on fossil fuels for about 85 percent of all of our energy. The remaining 15 percent, nuclear provides about 8 percent of it; 20 percent of our electricity; 8 percent of our total energy. And we are at 7 percent renewables.

So if in fact it is true, and I think it is true, that we are at peak oil, and no matter what we do, we are not going to pump more oil in the future. It is going to be less and less and less for about another 150 years, until we run down the other side of Hubbert's Peak. It is not like we are running out of oil. We are just running out of our ability to produce a lot of oil really cheap, enough to meet the demands of a growing economy which requires about two percent.

I am very interested in the possibilities of making some of our commercial power from power plants that we would also use in our military. I noted during the break we were discussing that we are about the only society in the world that can afford the luxury of evaporating drinking water to get rid of the excess heat from our power plants.

In just about all the rest of the world, the power plant is situated in a city near people, and the surplus heat they use for what is called "district heating," and with an ammonia cycle refrigeration, you can cool your home with that, as well as you heat your home in the wintertime.

Maybe I am a dreamer, but I can envision the day when we are making thousands of nuclear power plants that we are now distributing through the cities. I can be from here to that chair, sleeping near your nuclear reactor in the submarine. I have less radiation than if I am laying out on the beach. Correct?

Admiral DONALD. That is correct.

Mr. BARTLETT. Okay. So I have no reason to believe that they wouldn't be perfectly acceptable in the cities. We have a very long history. You gave the statistics, which were stunning, about how many man-years and how many steaming hours you had, and not a single accident or even a hint of an accident.

I would like you to give us for the record how many homes we could provide with electricity from one of your nuclear power plants. I would like to know if you were, maybe like Henry Ford made his Model T on an assembly line, rather than at the local buggy works, which is the way they made the buggies before he put a motor in it, how much we could save in producing these power plants.

As I mentioned, Admiral Donald, I look forward to the day that our nuclear power plants for our military vessels are commercial off the shelf. You noted that the commercials wouldn't need to have the hardening that you have for vibration and so forth, but you get what I am saying. I just think we have an enormous potential here to meet an incredibly important need in our country to provide power from other than fossil fuels.

I might note that there are three groups that have common cause here. One is the group that believes that greenhouse gas production is producing global warming. I think they are probably correct. There is a second group—Jim Woolsey and McFarland and a whole bunch of others that wrote a letter to the President probably 2 or 3 years ago now saying, "Mr. President, the fact that we have only 2 percent as known reserves of oil, and use 25 percent of the world's oil, and import almost two-thirds of what we use, is a totally unacceptable national security risk."

So certainly, those interested in the national security implications of peak oil have common cause with those who are concerned about greenhouse gases and global warming. I am concerned about both of those, but I am even more concerned about the fact that even though we may with dumb luck get through those, there is no dumb luck that will get us by peak oil, if these studies are correct, and if T. Boone Pickens is correct that we are now peaking in oil production.

I hope I am wrong, but I believe that the over-arching issue in the next decade is going to be energy. It is going to dwarf everything else, and we will realize that we have been majoring in minors here in the Congress with all these things that we are focusing our attention on.

So I see a big, big potential for the knowledge that you all have to contribute in a very big way to our society, and to benefit from that in getting much lower production costs for your nuclear power plants. Am I wrong?

Admiral DONALD. Certainly, if we produced more, and we talked about that already, about dissipating overhead. You do more, it does gain you some cost savings.

What I would like to do is take your questions for the record, because I haven't spent a whole lot of time thinking about applications for the power plants as ideal for a commercial use. So I will take those for the record and we will get back to you.

The other thing I would add to the discussion is, while we do have a safety record that we are certainly very proud of, and we guard jealously, and we also understand that you are only as good as your last safe day of operations, that you can never let down your guard.

We have to maintain vigilance. As you are well aware, it doesn't come easy. There is a tremendous amount of effort, oversight, and energy involved, personal energy involved on the part of a number of people in our organization to make sure that those standards are sustained, and that you do continue safe operations.

So the idea of proliferation of many reactors throughout the nation, we just would have to keep in mind that that comes with an overhead to make sure that you are being proper stewards of the public trust and protecting the environment, protecting their safety as well. Otherwise, a problem there would create a problem for all of us in the nuclear industry. So I would just be cautious in an idea of thousands of these things around and doing that type of work, but I will take your questions and we will get back to you.

Mr. BARTLETT. Thank you. I would like to suggest that the alternative of shivering in the dark, which will be a very real alternative, will make the minimal risks involved with nuclear quite more acceptable.

Admiral DONALD. Yes, sir.

Mr. BARTLETT. Mr. Chairman, thank you very much for a good hearing.

Panel, thank you very much.

Mr. TAYLOR. Thank you, Mr. Bartlett.

I have come to become a believer in Mr. Bartlett's theory as far as peak oil. Whether he is 100 percent right or half right, he is right. It is just a matter of sooner than later. I am convinced that 50 years from now, every surface combatant will be powered by something other than what we are powering ships with now. It is going to be nuclear or something beyond that.

So the argument of whether or not we are still using diesels and turbines in major surface combatants I think is off the table 50 years from now, and probably off the table 25 years from now.

With that in mind, that the future is nuclear powered, I think Admiral Rickover was right, if not premature, and you know, we have a yard that predominantly makes submarines, a yard that predominantly makes carriers, two yards that predominantly make surface combatants, going back to my previous question.

If the future is nuclear power, and if those two yards wanted to stay in the surface combatant business, what is the investment on the part of an Ingalls? What is the investment on the part of a Bath, to make themselves ready for the future?

Admiral DONALD. With respect to nuclear certification?

Mr. TAYLOR. Yes.

Admiral DONALD. That is the specific question? What I would like to do is, in addition to the remarks I made prior to define what it would take, what I would request is to take that question for the record and maybe put some numbers against that and get back to you.

Mr. TAYLOR. The third thing, Admiral Donald—and I know nothing is ever as simple as we would like it to be—one of the great things about our gas turbine is that we can drop it down the stack or remove it through the stack.

If the option would be for a very substantial portion of that ship to be built and then to be engineered in a way where the nuclear power plant could be installed or removed, if that is even an option, and I know that this is actually a lot more complex than a gas turbine, but using that analogy, could a ship be designed so that to a very large extent it could be made as a ship and then towed to one of the places and installed? I would be curious.

Admiral DONALD. As Admiral Sullivan pointed out, we do do modular construction. In fact, we do that in the *Virginia* class today. If we are talking about, again going back to the previous discussion that we had about the realities of the next generation of surface ships, whether CGX or not, if we really are interested in a nuclear variant, the only thing that I would say is that one of the assumptions we made is that you would be using existing components to the extent you could, with a minimum of redesign.

The idea that we would create a modular power plant now to meet the need of the next generation of surface combatant would probably add significant complexity and significant costs to what you would be talking about doing. So probably not for the next generation, but if you were looking at something beyond that, then we would certainly look at it, and we would look at modular by any stretch of the imagination, just in the course of business.

But we have not spent a whole lot of time and energy at naval reactors looking at a modular-type design to be dropped into a plant or a ship in the sense that a gas turbine would be—at least not yet. And that was not the assumption that we used in the study or in any other work we did associated with the study.

Mr. TAYLOR. This would be for the panel: What do you think is the timeline for a working directed-energy weapon? How far away are we from that? Are we five years from it, 15 years from it?

Admiral MCCULLOUGH. We have a prototype railgun down in Auburn, but that is not directed energy. We are looking at 2022 to weaponize that. So now you are talking about something that is directed energy that is in the real early stages of development, so I don't see it anytime before that.

Mr. TAYLOR. Is the railgun, like the radar, energy intensive?

Admiral MCCULLOUGH. Yes, sir. At this stage of the game, yes, sir.

Mr. TAYLOR. And the form of energy is?

Admiral MCCULLOUGH. It is electricity stored in a capacitor bank, the one we have at Auburn.

Mr. TAYLOR. And if you can, give me a term of how much energy would be required for that.

Admiral MCCULLOUGH. It is just about 20 megawatts of swing power. When you shot it, that is what you would have to recharge to.

Mr. TAYLOR. Okay. So that is 20 megawatts, plus the 31 megawatts for the theater missile. Would one of the power plants out of a carrier, if we were to put that into a cruiser, would that supply enough energy to power the cruiser, power the missile defense, and power the railgun?

Admiral DONALD. The calculations, the assumption that we made with the power plant for the next-generation surface combatant, or the medium-size surface combatant, would meet the needs for the operating profile, plus assumptions for the radar.

I don't believe it included railguns in it. I would defer to them on that. It left margin in for growth in the ship to the tune of about 25 percent during the life of the ship. So that is a rough approximation, given what we know about what this shop could possibly look like, but it did include margin.

Mr. TAYLOR. Okay, one last question before I yield to my ranking member.

I am very much impressed with the thoroughness of your report. I am obviously pleased with the conclusion. You did stop short of saying the United States Navy has said "our submarines will be nuclear." The United States Navy has said, "Our carriers will be nuclear." You stopped short of saying it is the recommendation of the United States Navy to have a nuclear-powered cruiser.

I am curious why.

Secretary ETTER. I would suggest that we are really waiting on the analysis of alternatives. We believe we need that data in order to be able to determine what really is the right path ahead. We think that study is of sufficient detail and, as we discussed earlier, some of the key things that are driving that are the radar. But we believe with the results from the analysis, that we will be able to determine what would be the right path ahead.

Mr. TAYLOR. Madam Secretary, what is the timeline on that report?

Secretary ETTER. We are looking for the report to be out toward the end of the year. I would ask Admiral McCullough to explain the steps that are still needed to finish that.

Admiral MCCULLOUGH. Yes, ma'am. We have broken the AOA, the analysis of alternatives, into phases because different parts of the analysis will drive subsequent parts. As I said earlier, a lot about our sensitivity has to do with the size of the aperture. So once you look at the potential threat in the 2024 timeframe, and then we look at a projected threat through the engineered service life of the ship, we will know how big the aperture has to be for the radar.

The aperture size will drive the size of the deck house. We expect to have the radar analysis done by the end of June. And then we will start the development of the radar, the further refinement in the radar in the program. Once you know how big the deck house is, based on the radar, you will understand how big the hull on the ship has to be.

Then. given the hull size, we will evaluate the propulsion plant that needs to go in the ship, again with the growth to achieve capability throughout the engineered service life of the ship. We anticipate that that part of the study will conclude late in the fiscal year to support our milestone decision.

Mr. TAYLOR. Great. Thank you.

What is the status of the direct energy conversion in lieu of the steam conversion?

Admiral DONALD. Really since 1988, we at naval reactors have had an evolving process of looking at alternatives for using the nuclear energy in more efficient, more effective, more innovative ways to generate power, as opposed to what we do today with a pressurized water reactor that has become so popular. There have been a number of technologies we have looked at.

One that we did look at was called a thermophotovoltaic energy transfer process. We studied that in some depth, and in fact made some significant strides in that. For instance, the efficiency of the thermophotovoltaic collector, when we first started this work back in the mid-1990's, the best you could hope for was an efficiency of about four percent. When we completed the work that we have done to date on that, we had the efficiency in upwards of about 20 percent, which has never been done anywhere.

We felt that we had taken that technology about as far as we could, with the idea that it would be available for a ship application in the foreseeable future. The difficulty that we ran into had nothing to do necessarily with the technology we were investigating, but it involved different types of reactors that you would need to generate the heat. In other words, you are talking about a factor of about four or five hotter reactors that you would have to have, that would run at an elevated temperature to make this work.

That just is not feasible in a ship that you and I can foresee today. So what we have done is we have wrapped that technology up and we have placed it on the shelf. We are looking at other possibilities to take advantage of nuclear energy on ships. We continue to press the envelope in that regard. But right now, for practical applications for shipboard use, the pressurized water reactor remains the best alternative for the foreseeable future.

Mr. TAYLOR. Thank you, Admiral.

Mr. Bartlett.

Mr. BARTLETT. In 2 months and 13 days, on May 14, it will be the 50th anniversary of a talk that Hyman Rickover gave to a group of physicians in Minnesota. If Google can't find it for you, call our office and we will get you a copy of the talk.

If you thought he was a great intellect, after you read that talk, you will agree he was a great, great intellect. It is on energy. I would encourage you to get the talk. It is just a fascinating talk. He was a man really, really interested in a lot of different areas, and you will be fascinated by his talk.

Mr. TAYLOR. Last question, and I do mean last question.

The additional expense, if at Bath or Ingalls, it would have to get nuclear certified? Is there any benefit to that, as a result of doing that, that is translated to other conventionally powered ships? Do they get better at anything? Does the process become more efficient in any way, safer in any way? It is a matter of curiosity on my part.

Admiral DONALD. I would say, one of the things that we do take some degree of pride in in our business is that we do believe we have a rigorous engineering approach to our business in a formal way. We do work very hard to put processes in place to ensure safety and ensure effectiveness, and to ensure efficiency in the way we do our business. So in that sense, we like to think that we could make any organization better, just by maybe taking on some of the things that we do.

But beyond that, I am not sure I would be the one that would be in a position to assess what advantage that would be to a commercial business or not. There are some things that we do that because of the level of detail and obviously we are concerned about the consequence of should things go wrong. We do put layers of defense in place and we do get into a degree of detail that probably some other industries would find to be somewhat cumbersome, but are necessary if you are going to manage a complex technology, an unforgiving technology like nuclear.

So I am sure there are some pluses or minuses in that, but I think it would be better to ask commercial industry how they felt about that.

Mr. TAYLOR. Admiral Sullivan, I am just curious, obviously the pressure requirements, the safety requirements on your welds for your piping and things of that nature, I have got to believe that those additional requirements have got to translate into an improved process throughout the yard. I was just curious.

Admiral SULLIVAN. As the admiral said, I think when you introduce the nuclear culture into a shipyard, it spreads and you get better. There is an overhead price to pay for that.

So, again, yes. If you introduce nuclear power engineering in all the things that Admiral Donald listed earlier—all of the testing, the certification, the engineering, the rigorous adherence to standards, the welds, and all of that—if that spreads across the yard, it is definitely an improvement, and everyone grows a culture of safety. That takes a long time and it costs a lot of money, so you would have to actually do the business case of is it worth going down that path.

Mr. TAYLOR. Okay.

Gentlemen, Madam Secretary, I thank you very much for being here.

The committee stands adjourned.

[Whereupon, at 5:16 p.m., the subcommittee was adjourned.]

APPENDIX

MARCH 1, 2007

PREPARED STATEMENTS SUBMITTED FOR THE RECORD

MARCH 1, 2007

Statement of Ranking Member Roscoe Bartlett
Seapower & Expeditionary Forces Subcommittee
Committee on Armed Services

Integrated Nuclear Power System for the Navy's Next Generation Surface Combatants

March 01, 2007

Thank you, Mr. Chairman. Good afternoon, ladies and gentleman. It's a pleasure to be here with you today to learn more about the conclusions and recommendations of the alternative propulsion study conducted by the Navy over the last fiscal year. For some time, I have been an advocate for the use of nuclear propulsion for not only aircraft carriers and submarines, but for a range of surface ships, as well. I see a number of benefits, not the least of which is that such a move would be a major step towards reducing the military's dependence on fossil fuels. There is an overarching national imperative for the United States to reduce its demand for oil, given the limited quantities of this resource over the long-term, the strategic implications of importing oil from foreign nations, and the environmental consequences of burning fossil fuels. Yet, I can conceive of few greater improvements to mobility and warfighting capability, than a military which is not restricted by its refueling supply chain. Can you imagine a military like that? A Navy that can get anywhere quickly, because it does not need to stop and refuel? A Navy that can save significant investment in oilers and their associated manning? A Navy that is not vulnerable as its ships refuel? That's what I would call a disruptive technology.

Therefore, I would like to learn more about the report provided to Congress last month. The study concludes that the break-even cost for nuclear and fossil fueled versions of surface vessels are $210 per barrel of diesel marine fuel for large-deck amphibious assault ships and $70 per barrel for medium surface combatants. It would appear that the calculus is nearly there for surface combatants. I hope today's witnesses will discuss how these findings are being incorporated into the on-going analysis of alternatives for the next generation cruiser. I also hope the witnesses can elaborate on the differences between these findings and those of the 2005 Quick Look Analysis performed by Naval Reactors. In that study, the break-even costs were inverted – the break-even cost for large-deck amphibious assault ships was $80 per barrel and the break-even cost for a large surface combatant was $205 per barrel. Lastly, I would like to explore some of the assumptions underlying the study. For example, how was the fully burdened cost of delivery of fuel to the ship accounted and how were qualitative benefits, such as increased mobility and power delivery for weapons systems factored into this analysis?

With that, I'd like to conclude by thanking our witnesses for their service to our nation and for being here with us today. I truly look forward to your testimony.

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SERVICES COMMITTEE

STATEMENT OF

ADMIRAL KIRKLAND H. DONALD, U.S. NAVY

DIRECTOR, NAVAL NUCLEAR PROPULSION PROGRAM

BEFORE THE

HOUSE ARMED SERVICES COMMITTEE

SEAPOWER AND EXPEDITIONARY FORCES SUBCOMMITTEE

ON

NUCLEAR PROPULSION FOR SURFACE SHIPS

1 MARCH 2007

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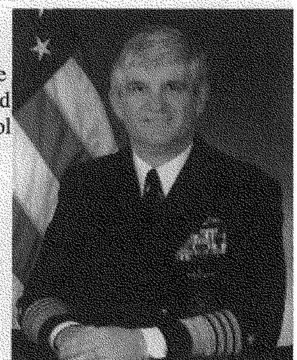
Admiral Kirkland H. Donald
Director, Naval Nuclear Propulsion



Originally from Norlina, N.C., Admiral Donald graduated from the U.S. Naval Academy in 1975 with a bachelor of science in ocean engineering. He also holds a master's degree in business administration from the University of Phoenix and is a graduate of Harvard University's John F. Kennedy School of Government Senior Executive Fellows Program.

After completing his initial nuclear power and submarine training, he served in *USS Batfish* (SSN 681), *USS Mariano G. Vallejo* (SSBN 658), and *USS Seahorse* (SSN 669).

Adm. Donald was Commanding Officer, *USS Key West* (SSN 722), from October 1990 to February 1993. He served as Commander, Submarine Development Squadron Twelve from August 1995 to July 1997. From June 2002 to July 2003, he was assigned as Commander, Submarine Group Eight; Commander, Submarine Force Sixth Fleet (CTF 69); Commander, Submarines Allied Naval Forces South; and Commander, Fleet Ballistic Missile Submarine Force (CTF 164) in Naples, Italy. Most recently, he served as Commander, Naval Submarine Forces; Commander, Submarine Force, U.S. Atlantic Fleet; Commander, Allied Submarine Command; and Commander, Task Forces 84 and 144 in Norfolk, Va.

His shore assignments include the Pacific Fleet Nuclear Propulsion Examining Board and the staff of the Director, Naval Nuclear Propulsion. He also served at the Bureau of Naval Personnel, on the Joint Staff, and as Deputy Chief of Staff for C4I, Resources, Requirements and Assessments, U.S. Pacific Fleet. Adm. Donald assumed his current duties as Director, Naval Nuclear Propulsion, on 5 November 2004.

Adm. Donald is authorized to wear the Navy Distinguished Service Medal, Defense Superior Service Medal, Legion of Merit with four gold stars, and the Meritorious Service Medal with one gold star, in addition to several other personal and unit awards.

Introduction

Mr. Chairman, distinguished members of the Seapower and Expeditionary Forces Subcommittee, thank you for inviting me here today to testify on Integrated Nuclear Power Systems for Future Naval Surface Combatants.

The Naval Nuclear Propulsion Program began under the leadership of then-Captain Hyman G. Rickover in 1948. It began with a vision of harnessing the power of the atom to propel a submarine, freeing it from internal combustion engines. While a seemingly impossible feat at the start, Admiral Rickover not only saw his vision come to reality on January 17, 1955, when USS NAUTILUS steamed out of New London, Connecticut—UNDERWAY ON NUCLEAR POWER—he continued on to revolutionize marine powerplants for cruisers, aircraft carriers, and deep-diving submersibles. More so, the virtually limitless power, endurance, and flexibility afforded by these plants revolutionized naval warfare by providing the capability of sustainable, persistent combat power to quickly respond where needed around the globe.

Admiral Rickover developed an organization bound by a few simple core principles: technical excellence, quality, integrity, cost-consciousness, concern for personnel, and proper stewardship of the environment. Today, as the fourth successor to Admiral Rickover, I oversee and support 103 reactor plants in 81 nuclear-powered warships, the Submarine NR-1, and four training and test reactor plants. Since 1955, we have safely operated more than 5,800 reactor years and steamed over 136 million miles.

I am responsible for the research, design, development, acquisition, testing, maintenance, operation, and training of personnel for the Navy's nuclear propulsion applications; and also for the direct supervision of the Bettis and Knolls Atomic Power Laboratories, Bechtel Plant Machinery, Incorporated, the Expended Core Facility at the Naval Reactors Facility in Idaho, and naval reactor prototype plants. As specified in Executive Order 12344 and later set forth in Public Laws 98-525 [1984] and 106-65 [1999], Director, Naval Reactors, has statutory authority for oversight and direction of all aspects of naval nuclear propulsion. I fulfill these responsibilities through the management and oversight of a network of dedicated research labs, training facilities, plus the nuclear-capable shipyards, and equipment contractors and suppliers—the nuclear industrial base.

Unparalleled Record of Performance

Our nuclear safety record is unparalleled. U.S. nuclear-powered warships have safely operated for more than half a century without experiencing any reactor accident or any release of radioactivity that had an adverse effect on human health or the quality of the environment. The Program has consistently limited personnel radiation exposure more stringently than the civilian nuclear power industry or other Government nuclear programs have. No civilian or military personnel in the Naval Nuclear Propulsion Program have ever exceeded the Federal lifetime radiation exposure limit or the Federal annual limit in effect at the time. In the last decade, the average annual radiation exposure for operators has dropped to about one-eighth of the average annual exposure the typical American citizen receives from natural background radiation exposure. Simply put, the average American will receive more radiation from cosmic and natural terrestrial sources than our operators get from operating our nuclear propulsion plants.

This low occupational exposure record has been achieved by putting priority on the safety of our operators and the public, and then translating that priority to reality through rugged, conservative plant designs.

That record of safety pays off in many ways. One important example of this is our access to ports, both domestic and foreign. Nuclear-powered warships are welcomed today in over 150 ports in more than 50 countries worldwide, allowing them to carry out their mission without constraint.

Typical Naval Nuclear Propulsion Plant

In naval nuclear propulsion plants, fissioning of uranium atoms in the reactor core produces heat. Since the fission process also produces radiation, shielding is placed around the reactor to protect the crew.

U.S. naval nuclear propulsion plants use a pressurized-water reactor design, which has two basic systems: primary and secondary. The primary system circulates ordinary water in an all-welded, closed loop consisting of the reactor vessel, piping, pumps, and steam generators. The heat produced in the reactor core is transferred to the water (which is kept under pressure to prevent boiling). The heated water passes through the steam generators, where it gives up its energy. The primary water is then pumped back to the reactor to be heated again.

Inside the steam generators, the heat from the primary system is transferred across a watertight boundary to the water in the secondary system, also a closed loop. The secondary water (which is at relatively low pressure) boils, creating steam. Isolation of the secondary system from the primary prevents water in the two systems from intermixing, keeping radioactivity out of the secondary water.

In the secondary system, steam flows from the steam generators to drive the main propulsion turbines, turning the ship's propeller and the turbine generators, which supply the ship with electricity. After passing through the turbines, the steam is condensed into water, and feed pumps return it to the steam generators for reuse. Thus, the primary and secondary are separate and closed systems, in which constantly circulating water transforms energy produced by the nuclear reaction into useful work.

There is no step in this process that requires the presence of air or oxygen. This, combined with the ships' capability to produce oxygen and purified water from seawater, enables the ship to operate completely independent of the Earth's atmosphere for extended periods of time. In fact, the length of a submerged submarine patrol is limited primarily by the amount of food the ship can carry for the crew.

Advantages of Nuclear Power

Nuclear propulsion gives our warships virtually unlimited endurance at high speed, worldwide mobility, and unmatched operational flexibility. Without the encumbrances of fuel supply logistics, our nuclear-powered warships can get to areas of interest quicker, ready to enter the fight, and stay on station longer than their fossil-fueled counterparts.

On September 11, 2001, the nuclear-powered aircraft carrier USS ENTERPRISE (CVN 65) was on her way home from a 6-month deployment when she learned of the deadly terrorist attacks on the U.S. via satellite television. Even before receiving orders, ENTERPRISE executed a right full rudder order and was within striking distance of Afghanistan less than 11 hours without the need to pre-position a logistics train. This is just one example of the flexibility that nuclear power brings.

Nuclear submarines similarly benefit from the improved mobility and endurance, but also gain the tactical advantage of stealth afforded by unlimited submerged operation and the virtually limitless energy to power the onboard sensors.

We have successfully built and operated nine nuclear cruisers in the past. They were originally designed to escort nuclear-powered aircraft carriers, thereby giving large portions of carrier battle groups unrestricted operational flexibility. Although these cruisers performed superbly for many years, limited resources drove their obsolescence: the Navy chose not to update their combat systems in the age of more modern *Aegis* systems.

As ship designs advance to incorporate capabilities and warfighting needs that require more sustained energy (such as high-powered radars), nuclear propulsion—with its associated high energy density that comes without the need for large onboard fossil fuel tanks and fuel supply lines—is a viable design option. The recently submitted Report to Congress on Alternate Propulsion Methods for Surface Combatants and Amphibious Warfare Ships comes to the same conclusion.

We continue to improve the maintainability and affordability of nuclear propulsion through constant analysis of technical feedback from the Fleet and innovation from our laboratories. The experience we have gained has driven us to stick to our principles of ruggedness, reliability, redundancy, and safety, while capitalizing on new technologies and ideas. In so doing, we have striven to simplify designs and operating procedures, make components last longer, and better integrate systems.

The underlying principles involved in naval nuclear propulsion plant technology have not changed since Admiral Rickover first developed them. In the ensuing years since Admiral Rickover first briefed the Joint Committee on Atomic Energy, major technological advances have improved the performance and reduced costs of naval nuclear propulsion plants. For example:

- Since the 1960s, Naval Reactors has achieved a 30-percent increase in energy density of naval nuclear propulsion plants.

- Life-of-ship cores have become a reality for our submarine force. For example, the originally installed core in USS NAUTILUS had a life of 2 years; the USS VIRGINIA core is expected to last 33 years.

- Current surface ship cores have a 15-fold increase in energy content compared to surface ship designs in the 1960s.

- The design for our newest aircraft carrier propulsion plant, the GERALD R. FORD class, reduces the reactor department manning by 50 percent as compared to crewing requirements for NIMITZ-class ships.

- Propulsion plant maintenance requirements for the GERALD R. FORD-class ships are 30 percent less than for NIMITZ-class carrier propulsion plants. This decreased maintenance can be directly translated into increased operational availability.

The Question of Cost

While the formidable advantages of nuclear propulsion come with some cost, those costs are often mischaracterized. Construction of nuclear-powered ships requires integration of a sophisticated nuclear quality control and testing infrastructure into the process. Construction must be done correctly—up front—as many of the nuclear systems are, in practicality, inaccessible throughout the life of the ship. In addition, the acquisition cost for submarines includes all of the propulsion fuel necessary to support a ship throughout her lifetime. Although nuclear-powered aircraft carriers require a midlife refueling, the cost of about 23 years of reactor fuel is included in their upfront acquisition cost. Finally, we require nuclear-powered ships to be properly maintained and disposed of.

The advantages provided by nuclear propulsion increase the acquisition costs of the ship being procured. Studies conducted by the Navy in FY06 indicate that this upfront acquisition premium averages $600M per ship. When comparing life-cycle costs, the nuclear propulsion premium varies from 0 to nearly 40 percent, depending on ship operational tempo, service life, and mission requirements. These cost premiums need to be weighed against the operational advantages provided when making decisions on propulsion type. For example, when the Analysis of Alternatives for what is today the GERALD R. FORD-class aircraft carrier was completed in the mid 1990s, it was decided that nuclear power was the best choice as operational benefits outweighed the projected life-cycle cost premium of less than 10 percent. Current analyses indicate that nuclear propulsion is now the optimal choice—both economically and operationally—for aircraft carriers.

Selection / Training of People

As Director, Naval Nuclear Propulsion, I am responsible for maintaining the high standards first established by Admiral Rickover for selecting, training, and qualifying nuclear personnel. The availability of nuclear power for future ships is dependent on continued safe and effective operations by highly trained and competent personnel, both at sea and in port.

Since inception, over 114,900 officers and enlisted technicians have been trained in the Program. The officer selection process accepts only applicants who have high academic standing in colleges and universities. All personnel receive 1-2 years of training in both theoretical knowledge and practical experience on operating reactors that mirror those used in today's ships. Even after completing this training, the personnel must spend several months qualifying on the ship to which they are assigned before manning a key watchstation. In addition to the training and qualification program, multiple layers of supervision and inspections are used to ensure a high state of readiness and compliance with safety standards. When a ship's reactor is in operation at sea, there are senior enlisted technicians and officers on duty with a combined total of, on average, 40 years of experience in naval nuclear propulsion. The cost of maintaining this personnel community is accounted for in the total life-cycle cost calculation that will be evaluated against other potential alternatives. Into the foreseeable future, my training pipeline has the capacity without further infrastructure investment to produce the additional personnel required by future classes of nuclear ships currently being debated.

Maintenance and Disposal

We maintain our nuclear-powered ships to the high standard needed to ensure propulsion plant integrity. Nuclear propulsion is an unforgiving technology requiring numerous complex maintenance actions that cannot be deferred. Over the years, we have reduced the maintenance to only those actions that have to be done to operate the ship safely and reliably. For example, we have designed the next-generation aircraft carrier propulsion plant with a 30 percent reduction in required maintenance. We have also developed a maintenance infrastructure capable of accomplishing the maintenance as efficiently as practicable. When the proper investments in preventative maintenance are made throughout the life of the ship, a nuclear-powered warship's availability is equal to or better than fossil-fueled counterparts. These costs are included in the life-cycle cost considerations made in deciding naval ship propulsion types.

Admiral Rickover's cradle-to-grave responsibility across the propulsion plant lifetime mandates proper disposal of nuclear-powered ship reactor cores—and the ships themselves. Environmentally-conscious disposal of nuclear-powered ships has been ongoing since the mid-1980s. The technical complexities and costs of these efforts are well documented and well understood. Again, disposal costs are accounted for in the total life-cycle costs for nuclear-powered ships.

The above costs must be considered and balanced against the operational advantages afforded by nuclear power and projected affordability and availability of other fuel sources over the life of the ship when making the propulsion plant design choice. The Navy evaluates alternate propulsion methods for naval ship concepts, based on a varying set of factors. Mission and operating requirements and capability, balanced against the state of technology and total ownership cost, should drive the decision regarding the type of propulsion for a given platform.

Nuclear-Powered Ship Construction

Construction of nuclear propulsion plants requires unique skills, infrastructure, and administration to ensure that the high standards essential to safety and effectiveness are built into each component and the finished, integrated product. These attributes apply to many aspects of nuclear-powered ship construction—including areas outside of reactor core loading and propulsion plant testing evolutions, such as:

- Robust nuclear engineering, nuclear quality, nuclear test, and radiological controls organizations, having experience sufficient to preclude costly errors, delays, and rework.

- Facilities infrastructure, including lifting and handling, specialized assembly facilities, electrical power service, laboratory services, demineralized water production, testing infrastructure, and ship's crew support.

- Qualification and capacity of workforce, including trades, engineers, testers, inspectors, radiological control personnel, radiation health personnel, medical personnel, and corporate management.

- Certification of material and production processes, including nuclear-grade cleanliness, quality control, welding, non-destructive testing, radiological controls, radiation shielding, material identification and control, dosimetry, and radiography.

- Implementation of infrastructure, training, and processes and procedures required for naval nuclear propulsion security and force protection of a facility handling nuclear material.

- Capability, certification, support systems, and special tools and equipment to conduct nuclear testing, including turnover of operational control to ship's force.

- Onsite Government representation to support and oversee nuclear work.

- Contractor indemnification from nuclear liabilities.

- Strict adherence to environmental controls and ready response to emergencies.

- Authorization to safely handle and store radioactive materials associated with nuclear propulsion plants.

Northrop Grumman Newport News (NGNN) and General Dynamics Electric Boat (EB) are the Nation's two authorized and experienced nuclear construction shipyards. Both shipyards have been in this business since the 1950s. Today, NGNN builds and overhauls our nuclear-powered aircraft carriers and both EB and NGNN build submarines. NGNN previously built nuclear-powered cruisers in the 1960s and 1970s. The nuclear-capable shipyards are well below their capacity, both in new construction and maintenance. These existing nuclear-capable shipyards have sufficient capacity to accommodate nuclear-powered surface ship construction, and therefore there is no need to make the substantial investment in time and dollars necessary to generate additional excess capacity.

In addition to nuclear capable shipyards, as the Navy considers propulsion choices for future warships, the following matters apply to the nuclear propulsion alternative:

- We would use the existing nuclear industrial base to build the components for any additional nuclear-powered ships. We estimate that the increased workload could save the Navy 5-9 percent on propulsion plant component costs for new construction aircraft carriers and submarines through economies of scale and by applying the infrastructure overhead cost to a larger number of ships. Exact savings would be dependent on the number of new nuclear-powered surface ships. The additional workload would also bolster our fragile industrial partners, who are operating below their current capacity.

- The choice of propulsion for the Navy's next-generation cruiser will be driven by the mission requirements of that platform. If the Navy determines that this mission dictates the need to supply large amounts of energy for sustained periods, nuclear propulsion would compete favorably.

- Any new nuclear propulsion plant design effort would draw upon existing reactor plant designs to the maximum extent practical to minimize design cycle time and cost to promote commonality and capitalize on lessons learned. Ship specific design features and the degree to which reuse of existing technology is feasible would be determined once the Navy requirements are identified. Naval Reactors currently has a robust design force ready to meet the Navy's needs.

- Recruiting and retaining the best people we can find to operate our ships is key to our success. We continue to meet our goals, both in quality and in quantity. I see this as an advantage for the Navy: as all of our platforms become more technologically advanced, we will continue to need high-quality people.

In summation, the Naval Nuclear Propulsion Program stands ready to provide safe, reliable nuclear-propulsion plants for naval ships where appropriate both from a mission need and affordability standpoint. The Navy and the Defense Department have processes in place for ensuring that nuclear-propulsion is adequately considered in a fact-based analysis of alternatives regarding which type of propulsion is appropriate for naval warships. My program will continue to play a key role in that process.

Thank you for the opportunity to speak before this committee. I look forward to a continuing dialog on this topic. I will be happy to answer any questions at this time.

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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

NOT FOR PUBLICATION UNTIL RELEASED BY THE
HOUSE ARMED SERVICES COMMITTEE
SEAPOWER AND EXPEDITIONARY FORCES
SUBCOMMITTEE

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.

QUESTIONS AND ANSWERS SUBMITTED FOR THE RECORD

MARCH 1, 2007

QUESTIONS SUBMITTED BY MR. SESTAK

Mr. SESTAK. Shouldn't you be basing the break-even point cost on the variable cost of oil absent the cost of the infrastructure, because the infrastructure cost is going to be the same for many of the other ships?

Admiral SULLIVAN. Yes. The Report to Congress (RTC) breakeven cost analysis discriminated between power plant baselines based only on costs which were variable with the market price of crude oil and also which were discriminators between baselines. Although these variable burdened costs were included in the analysis, the breakeven data in the study is presented directly against the price of crude oil for ease of comparison to market prices. The below information provides a more detailed discussion of the burdening.

The RTC Studies burdened the cost of fuel to reflect the variable costs attributable to warfare and mobility mission energy consumption. Fuel burdening assumptions are:

- The baseline market price of fuel used in this analysis is $74.15 per barrel of crude oil, and its burdening buildup is shown below in the figure below.

Fully Burdened	**$152.95**
Direct (DESC)	**$96.60**
Crude Oil	$74.15
Refinement	$13.76
Transportation	$2.67
Facilities/Operations	$5.93
Mark-Up	$0.09
Indirect	**$56.35**
Storage & Handling	**$0.05**
Navy FISC	
Navy Barge	$0.05
Delivery	**$52.10**
Oiler Acquisition	$14.67
Oiler O&S/Charter Costs	$37.43
Environment	**$4.20**

- As the price of crude oil increases or decreases, the other elements of the burdened rate are assumed to remain constant with the exception of Oiler O&S/Charter costs. Fuel makes up 20% of the Oiler O&S/Charter costs; therefore, 20% is varied based on Crude Oil cost.

The RTC breakeven cost analysis assumed that all sources of burdening were applied to the fuel used to energize mobility and warfare mission systems in the power and propulsion plant variants in this study. The direct costs of burdening reflect the contracted price of product paid uniformly by the services to the Defense Energy Support Center. The Navy specific indirect burdening is based on the depreciated cost of Navy delivery assets (oilers), operating and support costs, and the cost of chartered asset fuel delivery. Acquisition costs of the oilers that support the groups of ships forming the surrogate future fleet modeled in the study were depreciated and proportioned to total fuel—Diesel Fuel Marine (DFM) (F76) and JP–5 (aviation fuel)—delivered. Only the variable, depreciated cost of Navy oilers apportioned to the DFM used by organic ship power and propulsion systems was included in the burdening. Other indirect variable costs attributable to other non-propulsion plant fluid delivery that are constant between propulsion plant baselines are not discriminators between power and propulsion systems and so were not included.

Excerpt from 1 March Testimony, House Armed Services Sub-Committee on Sea Power and Expeditionary Warfare is provided for context.

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