Examination of the Proposed Conversion of the U.S. Navy Nuclear Fleet from Highly Enriched Uranium to Low Enriched Uranium

by

Cameron McCord

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Abstract

The Treaty on the Non-Proliferation of Nuclear Weapons creates a loophole that allows a non-nuclear-weapon country to avoid international safeguards governing fissile materials if it claims that the materials will be used for naval nuclear propulsion purposes. The United States ability to negotiate a closing of this loophole is hampered by the fact that its entire nuclear fleet is powered by highly enriched uranium (HEU). In 1995, the U.S. Navy issued a report indicating that converting the nuclear reactors on its submarines and carriers from the use of HEU to the use of low enriched uranium (LEU) would create numerous problems. However, since that time significant technological advances in LEU fuel systems and naval propulsion strongly indicate that the issue of LEU conversion should be re-examined. This paper suggests that a high-level independent commission should be appointed and directed to thoroughly study the pros and cons of LEU conversion and to make recommendations to decision makers regarding what path should be followed.

Thesis Supervisor: R. Scott Kemp
Title: Associate Professor

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Chapter 1

Th Historic and Diplomatic Background

1.1 The NPT Loophole

The Treaty on the Non-Proliferation of Nuclear Weapons (NPT) is the primary international agreement controlling fissile materials and restricting their use in producing nuclear weapons.[1] The NPT requires that the five recognized nuclear-weapon States under the treaty the United States, Russia, the United Kingdom, France, and China are to negotiate to achieve nuclear disarmament and may not transfer nuclear weapons or other nuclear explosive devices to any non-nuclear-weapon State. In turn, the 184 non-nuclear-weapon countries are committed to not acquiring any such weapons or devices and are obliged to accept monitoring of their nuclear facilities and activities by the International Atomic Energy Agency (IAEA). [1] These monitoring activities are generally referred to as IAEA safeguards.

Article III of the NPT, which addresses the obligations of countries with regard to IAEA safeguards, states in relevant part:[1]

"Each non-nuclear-weapon State Party to the Treaty undertakes to accept safeguards, as set forth in an agreement to be negotiated and concluded with the International Atomic Energy Agency,...for the exclusive purpose of verification of the fulfillment of its obligations assumed under this Treaty with a view to preventing diversion of nuclear energy from peaceful uses to nuclear weapons or other nuclear explosive devices."

Thus, non-nuclear-weapon countries possessing fissile materials that could be used for nuclear weapons or nuclear explosive devices are subject to IAEA safeguards.[2] [3]

However, the NPT contains a major loophole that can be used by non-nuclear-weapon countries to exclude quantities of fissile materials from IAEA safeguards. In particular, the NPT implicitly allows non-nuclear-weapon countries to use fissile materials for military nuclear propulsion purposes without IAEA safeguards because IAEA safeguard agreements do not cover non-proscribed military activities. [4] Accordingly, fissile materials used for nuclear propulsion are exempt from any safeguards under the exclusive purposes clause in Article III, i.e., verification requirements apply only to materials that are intended to be used for nuclear weapons or nuclear explosive devices.[1] To avoid IAEA safeguards, a country would only need to declare to the IAEA that during the period of non-application of safeguards the nuclear material will not be used for the production of nuclear weapons or other nuclear explosive devices.[1] That country would never have to prove to the IAEA that it actually used the fissile materials for naval propulsion purposes.

The loophole in the NPT becomes especially significant when the fissile material in question is highly enriched uranium (HEU), i.e., uranium that has been enriched so that it contains more than 20% uranium-235. HEU poses a problem because it is more readily convertible to weapons grade materials, which contain more than 90% HEU.[1] Because most of the worlds nuclear submarines currently use HEU (rather than LEU) for fuel, it would not be surprising if a country chose to use HEU to power a new nuclear submarine. Thus, a non-nuclear-weapon country could announce to the IAEA that it will produce or stockpile a particular quantity of HEU for a nuclear submarine reactor to be constructed in the future but covertly intend to use the HEU for the production of nuclear weapons.[2]

An additional problem is that the existing NPT loophole may also be carried over in large part to the Fissile Materials Cut-off Treaty (FMCT), a proposed international treaty that will be negotiated in the future. In 1993, the United Nations General Assembly passed a resolution calling for negotiation of the FMCT.[5] The goal of the resolution is to ban the further production of any HEU or plutonium for use in nuclear weapons or nuclear explosive devices. The prohibition would apply to nuclear-weapon countries as well as non-nuclear-weapon countries and would effectively cap the amount of fissile materials available worldwide for nuclear weapons.[5] The successful finalization of the FMCT would be viewed as a major step toward full-scale nuclear disarmament.

However, it appears that the FMCT may contain a loophole similar to that contained in the NPT. As a result, non-nuclear-weapon countries would still be able to producc or acquire HEU and remove it from IAEA safeguards by claiming that it will be used for naval propulsion purposes. [1] In addition, efforts by the IAEA to verify the use of the HEU could easily be thwarted because countries could claim that reactor fuel designs and reactor operations are military secrets.[5]

1.2 New Urgency in Addressing the Loophole

Although the possibility of a country taking advantage of the NPT loophole has existed for many years, the need to address the problem has become much more urgent in recent years. The Deputy Commander of Irans navy announced in June 2012 that Iran is undertaking steps to use nuclear submarines in its navy.[2] A month later the director of Irans atomic energy agency stated that if Iran needed HEU to fuel submarine reactors or merchant ship reactors, his agency would simply inform the IAEA so that it could ensure Iran that it would have the required amount of nuclear fuel.[2] Given international concerns about Irans past interest in developing nuclear weapons, it is very easy to imagine that the HEU could be diverted for use in producing nuclear weapons.[6] It has been estimated that the HEU needed to power one small submarine could instead be used to construct two to six nuclear weapons.[7]

In addition, India, Brazil, Argentina, Pakistan, and Venezuela have also expressed their intentions to lease or build nuclear-powered submarines sometime in the near future. [2] Indias first submarine a nuclear-powered, ballistic submarine that will use HEU underwent sea trials in August 2012 and is expected to soon become operational. Brazil announced in 2008 that it was creating a nuclear submarine program and that it expected its first submarine to be operational by 2020. [8] Argentina announced in 2010 that it was developing a nuclear propulsion program with an emphasis on surface ships rather than submarines.[1] Pakistan announced in February 2012 that it plans to have a nuclear submarine operational by 2020. [2] Venezuelas intentions are vague, but it has indicated that it wants to build or purchase a nuclear-powered submarine in the near future.

1.3 Problems with the United States Negotiating Position

It is certainly in the interest of the United States and the international community at large to close the NPT loophole and to prevent the creation of a similar loophole in the FMCT. Otherwise, the loopholes provide opportunities for renegade countries to avoid IAEA safeguards and use HEU for nuclear weapons. The United States has endorsed the FMCT negotiations and has proposed that the treaty cover all HEU, not just weapons grade HEU (greater than 90% uranium-235) as proposed by Russia.[9] Moreover, the United States has worked to reduce civilian uses of HEU and to convert those facilities to the use of LEU. It has supported United Nations Security Council Resolution 1887, which in 2009 called upon all countries to minimize to the greatest extent that is technically and economically feasible the use of highly enriched uranium for civilian purposes, including by working to convert research reactors and radioisotope production. [2]

Despite the desire of the United States to convince the international community that loopholes permitting HEU use for naval propulsion without safeguards must be closed, the United States negotiating position is weakened by the fact that it uses HEU in all of its nuclear submarines and ships.[8] In fact, of the five NPT nuclear-weapons states, three of them (the United States, the United Kingdom, and Russia) use HEU in their nuclear submarines. (Both France and China use LEU in their nuclear fleets.) [2] One obvious way to close the loopholes is to agree that only non-nuclear-weapon countries are forbidden from using HEU in their nuclear-powered submarines or ships. As a result, all stockpiles of HEU would remain subject to IAEA safeguards, but such a position creates a double standard that has little chance of success. The United States would be in the difficult position of telling all the non-nuclear-weapons countries that it can use HEU for naval propulsion purposes but that they cannot. This significantly strengthens the bargaining position of those countries who want the loopholes to remain open, resulting in a potentially more dangerous situation where states can systematically circumvent all nonprolifcration and arms-control agreements.[2]

A second related reason for discouraging the use of HEU for naval propulsion is to reduce worldwide stockpiles of HEU that could be used for nuclear weapons.[2] This has been an important priority for the United States. The United States continued use and stockpiling of HEU for naval propulsion handicaps this effort. It is estimated that the worldwide HEU stockpile for naval propulsion fuel constitutes about 40% of the entire global military HEU inventory, and unlike surplus weapons HEU, will not be blended down to safe levels. As the United States and Russia continue to reduce the number of nuclear warheads that each side possesses in accordance with existing and future arms-reduction agreements, the percentage of global military HEU stockpiles comprised by HEU for naval propulsion fuel will become much larger. [8] Because such HEU stockpiles for naval propulsion fuel will likely become the dominant type of HEU worldwide, it is important that they be reduced as well.

Chapter 2

Feasability of the Navy Converting its Propulsion Reactors to Low Enriched Uranium

2.1 The Navys 1995 Report on LEU Conversion

The primary obstacle to improving the United States negotiating position with regard to the use of HEU is that the U.S. Navy has maintained that switching its nuclear fleet to LEU could create significant problems. In a 1995 report on the potential conversion to LEU from HEU, the Navys Office of Naval Nuclear Propulsion outlined several problems that it believed would result from converting its submarines and carriers to LEU. [10] Those problems fell into two main categories: (1) the use of LEU in existing submarines would require that nuclear cores be replaced before the lifetime of the submarine had otherwise ended; and (2) redesigning naval reactors and submarines to use LEU will be extremely expensive and disruptive. [10]

The report stated that conversion to LEU based on current reactor designs would significantly affect the endurance of the nuclear cores. For example, attack submarines that currently do not need to be refueled during their roughly 33-year lifetimes would need to be taken out of service two or three times for refueling with LEU.[10] The refueling process might involve cutting through a submarines hull in order to replace the nuclear core. In any event, submarines undergoing refueling would be out of service for extended periods of time, thereby effectively reducing the number of submarines available for sea duty at any given time. The report stated that each attack submarine (an SSN) would spend an additional 2 and years (8% of its life) in shipyards, and each strategic deterrent submarine (an SSBN) would spend an additional two years (4% of its life) in shipyards not available for sea duty.[10] In order to maintain fleet readiness, the Navy states that it would need to construct four additional SSNs and one additional SSBN. According to the report, the annualized cost of these additional submarines would be about $500 million.[10]

The Navy acknowledged that it could redesign its submarines and ships to accommodate a larger core based on LEU that would not need refueling during the vessels lifetimes.[10] The report indicates that, because LEU has a lower concentration of uranium-235, the nuclear core must be larger in volume in order to provide the same endurance. All else being equal, a core volume will require that the space provided for the reactor be increased. As a result, the Navy believes that its submarines would need to be redesigned to provide for this additional space demand. However, the report does not explain how the calculations of increased core volume were made and what assumptions were used to estimate what additional space would be needed in the reactor compartments.

With regard to designing new submarines, the Navy maintains that the same performance with a LEU core would require that the sizes and weights of the reactor vessel, pressurizer, and related components be increased to accommodate the larger core. This in turn would increase the size and weight of the reactor compartment and the shielding needed to protect the crew. As a result, the ships volume would need to be increased to add buoyancy to compensate for the additional weight.[10] According to the Navy, if attack submarines (SSNs) were redesigned to accommodate lifetime LEU cores (20% enriched), the machinery weight would increase by 18% and the hull diameter would increase by three feet. The Navy believes that such a heavier, larger submarine would be detrimental to tactical characteristics, would have a longer stopping distance, and might be less maneuverable. [10] The Navy acknowledges that a lifetime LEU core could probably be fit into an SSBNs larger hull without redesigning the hull although the greater weight would need to be addressed during the design phase.[10]

The report further states that the costs of converting the nuclear fleet to LEU would be substantial. It estimates that, if current reactor designs are not changed, maintenance costs would increase by about $1.8 billion per year (in 1995 dollars and assuming a 1995 baseline) and that additional submarine and ship construction would be necessary to provide the same at-sea force levels.[10] Alternatively, if submarines and ships are instead redesigned to accommodate larger LEU cores, the report indicates that the one-time redesign costs would be about $4.7 billion, and increased construction costs for new submarines and carriers based on natural replacement rates would be about $1.1 billion per year more for LEU-fueled vessels as compare to HEU-fueled vessels.[10] The report additionally indicates that conversion to LEU would provide no technical advantage to the Navy and would actually be detrimental from an environmental perspective.

2.2 The Ippolito Study

Five years before the Navy issued the 1995 Report, Thomas Ippolito completed a study examining the tradeoffs that exist if LEU were used as a nuclear submarine reactor fuel rather than HEU.[11] His study addressed such factors as core life, core size, total power, and reactor safety. To evaluate these tradeoffs, Ippolito simulated three 50 MWt reactor designs using uranium fuel enriched to 7%, 20%, and 97.3% respectively. It was assumed that the 7% and 20% designs (LEU) were fueled with uranium dioxide (UO_2) in a caramel configuration, a design developed by France and currently used in all of its submarines. The design using the 97.3% fuel (HEU) was assumed to be a dispersion type.

Based on his data, Ippolito concluded that the 20% enriched core could have a lifetime of 20 years the same as the HEU core at that time if the core volume were increased to 1.7 to 2.5 times the volume of the HEU core. He also suggested that the U.S. Navys submarines could accommodate the increased core volume by switching to the French integral core design. Under this design, the reactor and the steam generator are integrated into one unit rather than being separated as under the U.S. Navy design. As a result, the space needed to house the reactor and steam generator under the French design would presumably be significantly less as compared to the U.S. Navy design.

Although the Ippolito study predated the 1995 Report, the 1995 Report did not refer to the Ippolito study nor did it expressly address any of the results and conclusions of that study. Because the 1995 Report was silent in this regard, the extent to which the elements of the Ippolito study were actually considered by the Navy is unclear.

2.3 The Study of Ma and von Hippel

In 2001, Ma and von Hippel published a study which addressed the 1995 Report and performed additional calculations based on alternative designs.[5] Their alternative designs were also based on the caramel fuel designs used by France in its Rubis-class submarines, which utilize LEU, and on data involving LEU-fueled Russian icebreaker ships. Starting with the assumption and results of Ippolitos study, Ma and von Hippel modified the core design modeled by Ippolito for the Rubis-class submarines to achieve power of 130 MWt approximately the power of a Los Angeles-class attack submarine.[5] They increased the size of the reactor core by 2.6 times to achieve the 130 MWt power. They then scaled up the core volume by an additional factor to increase the core life from 20 years (the result of Ippolitos study) to 33 years (the Navys goal for the newer, larger Virginia-class attack submarines). The resulting dimensions of the reactor core for LEU fuel were 50% larger than Ippolitos calculation but, according to the authors, were much smaller than the reactor compartment of a Los Angeles-class submarine. (However, it is still speculative as to whether the hypothetical LEU core would fit into the reactor compartment without modifying the size of the compartment.) Their conclusion was that the Navy could successfully pursue new, innovative reactor designs using LEU that would meet its size and performance requirements. In short, Ma and von Hippel concluded that the 1995 Report had been unduly pessimistic in assessing the possibility of converting the nuclear fleet from HEU to LEU.

2.4 The Study of Glaser and von Hippel

In a 2002 paper, Glaser and von Hippel maintained that the conversion of marine propulsion reactors to low-enriched fuel has thus far attracted relatively little attention even though the amount of HEU required for naval reactors is greater than the amount currently required for research reactors.[12] The authors argue that conversion of the worlds nuclear navies to LEU is important for nuclear nonproliferation, preventing terrorists from acquiring HEU, and verification under the proposed FMCT. The paper states that the 1995 Report did not adequately address the conversion issue and that the 1995 Report simply emphasized that conversion to LEU would not give the U.S. Navy any technical advantage. [12] In addition, the authors note that any independent review of the impact of propulsion reactor conversion to LEU on submarine performance is hampered by the fact that virtually all fuel and reactor design information is classified. [12]

2.5 The Miller Speech

In 2003, Professor Marvin Miller presented a speech in which he stated that [t]he challenge of converting existing HEU-fueled naval reactors, particularly submarine reactors, to the use of LEU fuel is more daunting than conversion of land-based research reactors.[13] He emphasized the lack of space on submarines and the difficulty of increasing reactor core volumes to maintain the same power and fuel lifetimes. He also maintained that the hostile and hazardous environments in which naval reactors operate might rule out the use of higher density fuels that can be used to convert research reactors to LEU. However, Miller also stated that it may be possible to design new nuclear-powered ships from the ground up to use LEU. [13] In this regard, he referred to the French Rubis-class submarines that use 7% enriched uranium and Ippolitos paper calculating that LEU enriched at 20% could extend the core lifetime to 20 years with an increase of core volume of about 2.5. He explained that the 1995 Report concluded that any significant increase in core volume would be unacceptable to the U.S. Navy and that the Navys goal is to build the best nuclear submarines in the world. According to Miller, [t]heir contention that attempting to increase the uranium density of the fuel sufficiently to compensate for going to LEU without an increase in core volume would simply compromise its performance is both strongly held and impossible to verify without access to classified documents.[13] Millers suggestion is that the U.S. Navy provide leadership by example by seriously investigating the potential for using new LEU fuels, possibly of the type being developed under the RERTR program to convert the remaining HEU research reactors, and also the possibility of non-intrusive but credible monitoring of the naval fuel cycle. [13]

2.6 The Ward Study

In a 2011 study, Ward examined the U.S. Navys assertions made in the 1995 Report and focused on its primary argument against conversion to LEU what she terms the economic penalty. [14] Ward first discussed the Navys stated reasons for resisting the conversion of its submarine reactors to LEU. She notes that the Navy cited a number of factors as being essential requirements and indicated that failure to meet any one of them would eliminate the use of a different reactor core and/or fuel system. She states that compactness (core size) and endurance (core life) are most often cited as the major obstacles to conversion.[14] However, one expert also maintained that maneuverability (the ability of a submarine to change powers rapidly and frequently) could also be compromised by a conversion to LEU.

With regard to core endurance, she states that conversion to LEU without significant fuel improvements would nominally require either an increase in core volume or more frequent refueling to compensate for the reduction in fissile content. [14] Thus, one of the key questions is whether conversion to LEU eliminates the option of having the reactor core function for the lifetime of the submarine without the need for refueling or whether development efforts could produce an LEU core with a suitable lifetime.

Ward also discussed Frances experience with conversion to LEU and its relevance to the issues raised in the 1995 Report. She states that all French submarines now contain reactor cores that use LEU designed as caramel fuel with the average enrichment being about 7%. She explains that a new class of French submarines the Barracuda class is scheduled to begin operation in 2015. The Barracuda-class submarine will be almost twice as large as the Rubis class submarine and will have an increased core life. The Barracuda-class submarines will be fueled by LEU caramel fuel with some improvements. [14] According to Ward, Frances new submarines show that improvements to core design have enabled increased power and/or longer core life, again suggesting that sincere efforts by the U.S. Navy to optimize reactor design for an LEU core could yield more impressive results than presented in the 1995 report. [14]

With regard to economic considerations, Ward asserts that [w]hile fuel conversion would no doubt prove costly for the U.S. Navy, it seems unlikely that cost concerns are truly driving the Navys opposition to conversion. [14] She explains that the 1995 Report set forth two main options for conversion: (1) maintaining current core volume and thereby reducing core life, or (2) increasing core volume and maintaining lifetime cores. If the Navy were to pursue the second option and completely redesign submarine reactor cores from the ground up, the Navy would face substantial upfront costs of $5.5 billion, but annual construction costs and operating expenses would be lower because fleet availability would not be adversely affected. Ward further contends that conversion to LEU would likely reduce the 1995 Reports projected annual operating costs because fuel fabrication costs for LEU should be lower, in part, because of decreased security requirements for LEU as opposed to HEU. [14]

Chapter 3

Balancing the Interests

As discussed above, it is important to ensure that countries are not able to use the NPT loophole to divert HEU for use in nuclear weapons and to reduce worldwide HEU stockpiles. The U.S. Navys use of HEU for its nuclear fleet is a major obstacle to reducing HEU stockpiles, closing the NPT loophole, and negotiating an FMCT that does not contain a similar loophole. Because 18 years have passed since the Navy issued its report on converting to LEU, the conclusions in the Navys 1995 Report should be revisited in light of subsequent developments. It is time to reconsider whether conversion of the Navys nuclear fleet to LEU is now technologically and economically feasible and a desirable measure from a geopolitical standpoint. Indeed, Congress has directed the Navy to prepare, by March 1, 2013, an updated report on conversion to LEU. However, that report has not yet been submitted to Congress.

With regard to technological developments, Frances submarine reactor design utilizing LEU has apparently worked very well and has indeed performed better than anticipated by the U.S. Navy in the 1995 Report. French submarines are able to produce more energy from LEU than are U.S. submarines because the French navy uses a more efficient LEU fuel design.[1] It utilizes caramel fuel – a uranium dioxide material embedded in a zirconium alloy grid. This caramel fuel increases the efficiency of the fission of uranium-235 so that lower enrichment levels can be used to achieve energy outputs equivalent to somewhat higher enrichment levels. [5]

Based on limited available information about the French design, studies have estimated that a submarine reactor using 20% enriched caramel fuel could have a core life of 33 years with a sufficient energy output and a relatively small reactor core volume.[5] Although the reactor core size of the United States submarines is classified information, some study authors have speculated that the caramel fuel reactor core could probably fit into existing United States submarines without the need to redesign the entire submarine. [5] Thus, it might be possible to retrofit U.S. submarines to utilize LEU as fuel more easily than suggested in the 1995 Report. At the same time, there may be problems in converting U.S. submarines to LEU usage that are not evident to outside observers. In short, it is important to investigate the technical elements of Frances design and consider how the success of that design should influence the Navys long-standing position that conversion to LEU should not be undertaken.

From an economic viewpoint, it makes sense to reconsider the projected costs of LEU conversion. Because retrofitting U.S. submarines to use LEU might not be as difficult as concluded in the 1995 Report, the costs of retrofitting or redesigning may be significantly less than the full costs of the major redesigning envisioned in the report. In any event, it makes sense to re-examine the basis for the cost assumptions and claims made in the report and determine what the costs of LEU conversion would be in todays environment.

The worlds geopolitical situation has changed considerably since the Navy issued the 1995 Report. The threat posed to the United States by Russia and its navy has continued to decline. [2] However, concerns about nuclear weapons proliferation have greatly increased as Iran and other countries have sought to develop new nuclear energy programs and, in some instances, to arm themselves with nuclear weapons. We now know that non-nuclear-weapon states can obtain and use centrifuges to make HEU more easily than previously assumed. Similarly, there are grave concerns about terrorist groups obtaining HEU by some means and threatening the international community. The need to prevent HEU buildup and diversion is even greater than before.

For these reasons, the relationship between technical considerations affecting the U.S. Navys nuclear fleet and the nations non-proliferation goals need to at least be reconsidered. As a high-ranking U.S. General recently emphasized, The [U.S. Nuclear Policy Review] elevated the prevention of nuclear proliferation and nuclear terrorism to the top of the policy agenda. [2] To a great extent, the ultimate resolution of the issues involving the continued use of HEU will require decision makers to balance the concerns and strategic needs of the U.S. Navy against the United States national security goal of preventing the proliferation of nuclear weapons. In any event, it is time to revisit the issues involving the Navys use of HEU with a new perspective.

However, it seems unlikely that the new report requested by Congress will, by itself, be the vehicle for undertaking the full, objective inquiry that is needed. Given its mission, the Navy can be expected to support the status quo on a good faith basis and to recommend against converting its nuclear fleet to LEU. Such a major program change will be very expensive even if LEU conversion is found not to be as difficult as concluded in the 1995 Report. The Navy will be extremely reluctant to recommend LEU conversion in this time of sequestered funds and shrinking budgets. In particular, from the Navys perspective, the billions of dollars that might be expended on LEU conversion could better be spent on constructing additional new submarines, developing new weapons systems, or continuing to improve submarine performance and safety.

This situation calls for an independent expert assessment of the pros and cons of LEU conversion. I suggest that a high-level commission be established to investigate thoroughly the technical and economic issues surrounding LEU conversion and to submit a separate report to the President and Congress setting forth non-binding recommendations for action. The commission could be modeled in part on the Blue Ribbon Commission on Americas Nuclear Future. That commission was established by the Secretary of Energy at the request of President Obama to address possible solutions to the nations nuclear waste problems.[15] Because the Naval Reactors Office is a unique agency that is part of both the Department of Energy (DOE) and the Department of the Navy, the Secretary of Energy could, in consultation with Navy officials, appoint the members of the Commission. Members could be, for example, former Navy Officers or former DOE officials with expertise in nuclear reactors, nuclear propulsion, or related areas; nuclear experts from the academic world; and former members of the Senate or House military committees.

It is important that all commission members be authorized to review classified documents during the inquiry. One of the major problems in reviewing the 1995 Report is that there is no way to accurately assess its conclusions because the underlying data, technical assumptions, and calculation methods are all largely unknown. Key information is contained in classified documents that are, of course, no available for review by the general public. For example, based on the 1995 Report, it is not possible to determine precisely how the Navy concluded that LEU conversion would necessarily require expansion of reactor compartments. There is no detailed discussion of compartment size requirements for current HEU-fueled submarines. Similarly, the report does not explain the extent to which the Navy considered use of caramel fuel designs such as those being used by France in its Rubis-class submarines.

Many of the problems with the 1995 Report are also likely to affect the new report requested from the Navy by Congress. Although that new report will obviously provide updates of technical and economic conclusions, it seems unlikely that the new report will reveal the underlying data, technical assumptions, and calculations that support the reports conclusions. Readers will still be forced to speculate as to the basis for the reports conclusions, and the question of whether the nuclear fleet should be converted to LEU will remain unresolved.

However, an independent commission with the authority to review classified documents will be able to examine the underlying data, technical assumptions, and calculations. Such a commission should be able to issue a report that fully and objectively discusses all the relevant issues without revealing classified information. At that point, decision makers can determine what path should be followed and whether, and to what extent, LEU conversion should take place.

If the Navy were to undertake a conversion from HEU to LEU in a portion of its nuclear fleet, one of the critical questions to be answered is when and how that conversion would take place. The most promising approach would be to include the conversion as part of the ongoing Ohio-class replacement program, which involves the development of new ballistic missile submarines (referred to as SSBN(X)s) to replace the Navys current SSBNs. In particular, since the replacement program is still in its early stages, it should be possible to design at least some of the SSBN(X)s to use LEU as fuel. Among other things, this would avoid potential problems associated with attempting to retrofit existing submarines in order to provide any necessary additional space for the LEU reactor core.

Because the Ohio-class SSBN replacement program will take place over many years, it should provide a reasonable opportunity to phase-in the use of LEU as fuel. The SSBNs entered service from 1981 to 1997 and serve as one leg of the U.S. strategic nuclear deterrent force triad.[16] Under the replacement program, the 14 SSBNs currently in service today will ultimately be replaced by 12 SSBN(X)s that will reflect the latest developments in technology and submarine design.[16] According to the FY2013 proposed budget, the Navy will begin retiring the SSBNs in 2027 and will continue to retire them at the rate of one submarine per year.[16] The first SSBN(X) is now scheduled to enter into service in 2030, and additional SSBN(X)s will enter into service at the rate of roughly one per year. For several years, the total number of ballistic missile submarines will drop to 10 the minimum number needed by the Navy but eventually 12 SSBN(X)s will be in service. It is expected that some SSBN(X)s will remain in service until the 2080s.[17]

Moreover, the SSBN(X)s projected lifetime of 42 years should not foreclose the use of an LEU core. As discussed previously, recent advances in LEU fuel systems and related technologies should make it possible to develop an LEU core with a life of at least 20 years.[16] The current plan is for each SSBN(X) to undergo a mid-life overhaul after 20 years in service. The overhaul would last for approximately two years, and then the SSBN(X) would be in service for an additional 20 years. While it is currently contemplated that the overhaul would not involve refueling, it seems that refueling could also take place at that time without significantly extending the time during which the submarine would be unavailable for sea duty.

One potential problem with deciding to convert all or some SSBN(X)s to LEU is that development of the SSBN(X) is in part a joint program between the United States and the United Kingdom.[16] Certain elements of the Ohio replacement program will be used to assist the UK in replacing its Vanguard-class ballistic missile submarines. The fact that the program is a joint project suggests that the United States ability to change design plans or modify timetables may be more limited than otherwise. The agreement between the U.S. and the UK indicates that the primary joint element of the program is the development of a modular Common Missile Compartment (CMC) that would be used in both the U.S.s SSBN(X)s and the UKs Vanguard-class successor. Because the design of the CMC apparently would not directly affect the design of the reactor core compartment, it seems that this aspect of the joint program should not significantly limit the Navys ability to undertake an LEU conversion. However, the U.S. is also assisting the UK in developing a new reactor plant to be used in its successor submarine, which could complicate the Navys efforts to convert to LEU fuel.[16]

Although 2030 the target date for the first SSBN(X) to enter service may seem to be very far away, consideration of whether LEU conversion can be undertaken for the SSBN(X)s should begin immediately. The intervening years will be needed to complete the submarines design, to construct the first submarine, and to test it thoroughly at sea. It is expected that construction of the lead ship will begin in 2019 or 2020 and will take about seven years to complete.[17] Because a significant amount of time will presumably be required to conduct research on LEU conversion and incorporate any necessary design changes, it is imperative that the process of considering LEU conversion begin as quickly as possible.

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