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The proposed Fissile Material Cutoff Treaty (FMCT) and its potential impact on U.S. Navy nuclear propulsion programs

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THESIS

THE PROPOSED FISSILE MATERIAL CUTOFF TREATY (FMCT) AND ITS POTENTIAL IMPACT ON U.S. NAVY NUCLEAR PROPULSION PROGRAMS

by

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March 2010

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This thesis examines the problems that United States Navy nuclear propulsion programs might encounter if the United States agreed to sign a version of the proposed Fissile Material Cut-off Treaty (FMCT) affecting the production of nuclear reactor fuel. The ultimate purpose of the FMCT is to contribute to the fulfillment of the goal of nuclear disarmament by terminating the production of plutonium and highly enriched uranium for weapon purposes. This thesis explores the potential impact of an FMCT on the U.S. Navy's nuclear propulsion systems. It also examines other options that might be available to the United States Navy to proceed with its nuclear propulsion programs (such as using low-enriched uranium as reactor fuel), as well as to maintain the security of its propulsion reactor designs.

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This thesis examines the problems that United States Navy nuclear propulsion programs might encounter if the United States agreed to sign a version of the proposed Fissile Material Cut-off Treaty (FMCT) affecting the production of nuclear reactor fuel. The ultimate purpose of the FMCT is to contribute to the fulfillment of the goal of nuclear disarmament by terminating the production of plutonium and highly enriched uranium for weapon purposes. This thesis explores the potential impact of an FMCT on the U.S. Navy's nuclear propulsion systems. It also examines other options that might be available to the United States Navy to proceed with its nuclear propulsion programs (such as using low-enriched uranium as reactor fuel) as well as to maintain the security of its propulsion reactor designs.

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I. INTRODUCTION

A. RESEARCH QUESTION

This thesis examines the problems that United States Navy nuclear propulsion programs might encounter if the United States agreed to sign certain versions of the proposed Fissile Material Cut-off Treaty (FMCT).

The goal of the FMCT is to reinforce nuclear non-proliferation norms. According to Article VI of the Nuclear Proliferation Treaty,

> Each of the Parties to the Treaty undertakes to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament, and on a treaty on general and complete disarmament under strict and effective international control.[1]

The ultimate purpose of the FMCT is to contribute to the fulfillment of the goal of nuclear disarmament by restricting the production of plutonium and highly enriched uranium for weapon purposes.

Moreover, as three Rand Corporation experts have observed,

> Another [goal] is to prevent terrorist and other subnational groups from gaining access to nuclear weapons or to sensitive nuclear materials, i.e., plutonium or highly enriched uranium (HEU).[2]

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[1] Information Circular, Treaty on the Non-Proliferation of Nuclear Weapons, *International Atomic Energy Agency*, http://www.iaea.org/Publications/Documents/Infcircs/Others/infcirc140.pdf (accessed September 25, 2009).

[2] Brian G. Chow, Richard H. Speier, and Gregory S. Jones, *The Proposed Fissile - Material Production Cutoff – Next Steps,* MR-586-1-OSD, (Santa Monica, California, Rand 1995), ix.

This thesis explores how great an impact the FMCT might have on the U.S. Navy's nuclear propulsion systems. The thesis also examines other options that might be available to the United States Navy to proceed with its nuclear propulsion programs, as well as to maintain the security of its propulsion reactor designs.

B. IMPORTANCE

In 1993, in a session of the United Nations General Assembly, President William Clinton proposed a treaty to stop the production of fissile materials for use in nuclear weapons.[3] According to a CRS Report for Congress,

> Some perceive a ban on producing fissile material for weapons as much more relevant today as it was a decade ago, a view supported by the Bush Administration's May 18, 2006 proposal."[4]

The report continues,

> Concern about terrorist access to large stockpiles of fissile material has only grown since the Cooperative Threat Reduction programs began in the early 1990s and particularly since September 11, 2001.[5]

Moreover,

> Revelations about Pakistani scientist A.Q. Khan's nuclear black market sales of uranium enrichment technology in 2004 have spurred efforts not only

[3] Sharon Squassoni, Andrew Demkee and Jill Marie Parillo, *Banning Fissile Material Production for Nuclear Weapons: Prospects for a Treaty (FMCT)*, CRS Report for Congress, http://fas.org/sgp/crs/nuke/RS22474.pdf (accessed September 27, 2009).

[4] Ibid., 2.

[5] Ibid.

to shut down these illegal networks, but restrict even "legitimate" technology transfers.[6]

Khan, who is best known as the father of Pakistan's nuclear weapon program, was a key player in Libya's effort to build nuclear weapons.[7]

Given the large amount of highly enriched uranium (HEU) and plutonium that is potentially available to possessors of enrichment and reprocessing facilities, the United States, along with certain other nuclear powers, wants to prevent another "nuclear black market." With this in mind, the proposed FMCT requires that states cease the production of fissile material for the purpose of building nuclear weapons. "The United States stopped producing HEU for weapons in 1964 and plutonium for weapons in 1988. Russia and the United Kingdom declared their cessation in 1995; France declared a halt in 1996." It is assumed that China halted its production of HEU, but the Chinese government has not publicly announced it.[8]

Some proposed texts for the FMCT would empower outside agencies to verify the compliance of a state's nuclear program with the treaty obligations. The International Atomic Energy Agency (IAEA) might be asked to verify and account for all fissile materials. Susan Koch has prepared a systematic and lucid exposition of the different

---

[6] Squassoni, Demkee and Parillo, *Banning Fissile Material Production for Nuclear Weapons.*

[7] David Albright and Corey Hinderstein, *"Unraveling the A. Q. Khan and Future Proliferation Networks,"* The Washington Quarterly, vol. 28 (Spring 2005).113–114, available at http://www.twq.com/05spring/docs/05spring_albright.pdf (accessed September 20, 2009).

[8] Squassoni, Demkee and Parillo, *Banning Fissile Material Production for Nuclear Weapons*.

approaches to defining fissile material for treaty limitation purposes as well as a "cut-off," plus divergent views on verification and participation in an FMCT regime. An FMCT could take many forms.9

C. PROBLEMS AND HYPOTHESES

The FMCT is currently at the proposal stage. The draft FMCT that the Bush administration submitted on 18 May 2006 is the only draft that any government has submitted, and it did not stipulate any provisions for international verification.[10] The draft FMCT was accompanied by a white paper that stated that

> even with extensive verification mechanisms and provisions — so extensive that they could compromise the core national security interests of key signatories, and so costly that many countries would be hesitant to implement them — we still would not have high confidence in our ability to monitor compliance with an FMCT.[11]

According to Arend Merburg and Frank N. von Hippel,

> The two primary concerns behind this conclusion appear to have been the difficulty of determining without unacceptable intrusiveness that HEU is not being diverted to weapons from the naval-reactor fuel cycle and whether undeclared fissile

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9 Susan Koch, "Fissile Material Cut-Off Treaty," in Taylor Bolz, ed., *In the Eyes of the Experts: Analysis and Comments on America's Strategic Posture: Selected Contributions by the Experts of the Congressional Commission on the Strategic Posture of the United States* (Washington, D.C.: United States Institute of Peace Press, 2009).

10 Arend Merburg and Frank N. von Hippel, *Complete Cutoff: Designing a Comprehensive Fissile Material Treaty,* Arms Control Today, http://www.armscontrol.org/act/2009_03/Meerburg_VonHippel (accessed September 20, 2009).

11 United States of America White Paper on Fissile Material Cutoff Treaty, The United States Mission to the United Nation in Geneva, http://geneva.usmission.gov/Press2006/0518WhitePaper.html (accessed September 10, 2009).

material production capabilities might be present in nuclear-weapon-related facilities.[12]

One of the various problems associated with certain proposed provisions of the FMCT stems from the fact that the U.S. Navy uses highly enriched uranium to fuel the propulsion systems of its submarines and its aircraft carriers. If the United States ratified the treaty, depending on its terms, the U.S. Navy might have to do what the French Navy did — that is, shift its nuclear reactor fuel from highly enriched uranium (HEU) to low enriched uranium (LEU).[13] This would be an expensive project, which the United States Navy does not wish to undertake.

Along with the possibility of switching to LEU as a naval reactor fuel, the United States is not in favor of allowing foreign observers to see the U.S. Navy's nuclear propulsion designs. Allowing foreign observers to inspect the U.S. Navy's nuclear propulsion programs could create a serious vulnerability in the national security of the United States, because some verification inspectors might decide to "go rogue" and sell the information they may have acquired on the U.S. Navy's nuclear propulsion program.

D. METHODS AND SOURCES

The thesis is based on unclassified sources, including government documents, scholarly articles, and press reports. The goal of the thesis is to clarify the options that might be available to the United States Navy to

[12] Merburg and von Hippel, *Complete Cutoff: Designing a Comprehensive Fissile Material Treaty*.

[13] Ibid., 3.

maintain its nuclear propulsion programs as well as the security of its propulsion reactor designs.

E. ORGANIZATION OF THESIS

This thesis is organized as follows: The introduction will describe the thesis topic and research questions and the importance of the research. The second chapter will review the origins and history of proposals for an FMCT as well as the history of U.S. policy regarding an FMCT. The third chapter will provide an analysis of how different treaty provisions in an FMCT could affect U.S. naval propulsion reactors. This includes the costs and risks associated with verification arrangements and modified reactor designs. The conclusion will present findings on the potential implications of an FMCT for U.S. naval nuclear propulsion systems.

II. THE ORIGINS AND HISTORY OF PROPOSALS FOR AN FMCT

A. BACKGROUND

The nonproliferation of nuclear weapons has been a long-standing objective of the United States, as well as other countries, since the bombing of Hiroshima and Nagasaki. After the Soviet Union successfully tested its atomic bomb (Figure 1), the United States and the Soviet Union embarked on a new phase of what was sometimes called the nuclear arms race. The United Kingdom, France, and China also acquired nuclear weapons. The spread of nuclear capabilities raised questions about the security and stability of nuclear deterrence.

Country	Date of first nuclear test	Date of accession to NPT
United States	July 16, 1945	1970
Russia	August 29, 1949	1970
United Kingdom	October 3, 1952	1970
France	February 13, 1960	1992
China	October 16, 1964	1992
India	May 18, 1974	–
Israel	?[92]	–
Pakistan	May 28, 1998	–
North Korea	October 9, 2006	1985 (withdrew 2004)

Figure 1. First nuclear weapons tests by current nuclear weapon states, 1945-2009.[14]

[14] Global Fissile Material Report 2009, International Panel On Fissile Materials, http://www.fissilematerials.org/ipfm/site_down/gfmr09.pdf (accessed November 17, 2009).

Concerned about the security and stability of the nuclear weapons era in prospect, the U.S. government sponsored a series of nuclear energy studies that became the foundation for the Baruch Proposal. Three studies are particularly noteworthy: the Jeffries Report, the Franck Report, and the Acheson-Lilienthal Report.

B. THE JEFFRIES REPORT

The Jeffries Report (sometimes referred to as the Prospectus on Nucleonics) was the first report to suggest how the U.S. government should address and develop nuclear energy.[15] Rebecca S. Lowen has described the context in which Zay Jeffries worked, as well as his basic conclusions:

> These advocates of atomic energy [in 1946] were former Manhattan Project scientists familiar with the rigidity of military supervision and fearful that its perpetuation would seriously endanger scientific freedom. As one prominent atomic physicist explained to the Senate Committee on Atomic Energy, the atom had numerous peacetime applications that might never be brought to the service of mankind if scientists' research was controlled by the military.[16]
>
> But while some scientists stressed the benefits to be gained from atomic energy to insure freedom for their research, those speaking about atomic energy in terms of its economic and technological feasibility were often more pessimistic than industry about the possibility of the early

[15] Henry D. Sokolski, *Best of Intentions*: *America's Campaign Against Strategic Weapons Proliferation* (Westport, CT: Praeger Publisher, 2001), 13.

[16] Rebecca S. Lowen, "Entering the Atomic Power Race: Science, Industry, and Government," *Political Science Quarterly*, Vol. 102, No. 3 (Autumn 1987), 464, http://www.jstor.org/stable/pdfplus/2151403.pdf, accessed (January 8, 2010).

> development of atomic reactors. As early as 1944, some scientists at the government-financed lab in Chicago assessed the possible peacetime applications of the atom in "A Prospectus on Nucleonics" and concluded that developing atomic power to produce electricity would not be particularly lucrative. Large scale atomic power plants in fact would probably never be developed, wrote Zay Jeffries, a scientist from General Electric and author of the report, because they would be extremely expensive to build and operate and would use up the little uranium that was available.[17]

Alexander Rabinowitch recalled how his father, Eugene Rabinowitch, who contributed to the Manhattan Project, had strong concerns about the use of atomic energy:

> Dad arrived in Chicago soon after the first controlled chain reaction in the windowless cellars below Stagg Field on December 2, 1942. Prior to the first chain reaction, the feasibility of developing an atomic bomb was uncertain. After Enrico Fermi's success, the creation of a bomb became likely, and project scientists began discussing the international political implications of atomic energy and how to convey their insights and worries about the future to the highest levels of government.[18]
>
> His first major contribution to formal consideration of these issues came in November 1944. He persuaded Robert Mulliken, information director of the Metallurgical Project and secretary of a committee formed to study post-war uses of atomic energy, to include a section in the committee's report on the political and social impact of atomic energy. The section, coauthored by him and Mulliken, emphasized the

[17] Lowen, "Entering the Atomic Power Race," 465.

[18] Alexander Rabinowitch, "Founder and Father," *Bulletin of the Atomic Scientists,* January-February 2005, 34, available at http://thebulletin.metapress.com/content/u3j77748416631v7/fulltext.pdf. (January 2, 2010).

> necessity of combining intensive development of nuclear energy with an effort to solve political problems worldwide. They argued that because it was inevitable that many nations would develop nuclear capabilities, a body to control military use of atomic energy must be created without delay. A final section of what came to be known as the "Jeffries report" emphasized the need to establish efficient international supervision over all military aspects of atomic energy and to educate the public on atomic energy and its dangers for world security.[19]

C. THE FRANCK REPORT

The second of these early nuclear studies was the Franck Report. This report, which was prepared for Arthur Compton, the director of plutonium production in the Manhattan Project, "was to explore how the development of atomic energy might be controlled after the war."[20]

According to Henry D. Sokolski,

> The Franck Report, written by some of the same authors as the Jeffries Report, reiterated that nuclear weapons advantaged offensive action and argued against the notion that the United States could stay ahead in a nuclear competition."[21]

According to Alexander Rabinowitch,

> The Franck report made two carefully reasoned points. First, the development of nuclear power was fraught with infinitely greater danger of mutual annihilation than all inventions of the past, that its secrets would not remain an American monopoly for more than a few years, and therefore the only way of avoiding a potentially disastrous nuclear arms race was to secure immediate agreement on international control of

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[19] Rabinowitch, "Founder and Father," 34.

[20] Sokolski, *Best of Intentions,* 13.

[21] Ibid.,14.

> nuclear energy. Second, the possibility of such an agreement would be gravely undermined if the United States first used the bomb in an unannounced attack against Japan. Prospects for agreement would be optimized if the destructiveness of nuclear power was demonstrated for the world on an uninhabited desert or barren island and used only if the demonstration failed to induce Japan's unconditional surrender.[22]

D. THE ACHESON-LILIENTHAL REPORT

The third report, the Acheson-Lilienthal report, was written by several of the top managers of the Manhattan Project in 1946. U.S. Secretary of State James Byrnes established a special advisory committee, headed by Under-Secretary of State Dean Acheson and the Chairman of the Tennessee Valley Authority, David Lilienthal, to prepare a report that the U.S. Government would present to the United Nations Atomic Energy Commission (UNAEC). The committee submitted its report to Secretary Byrnes in March 1946.[23]

Robert Oppenheimer wrote much of the so-called Acheson-Lilienthal report. Oppenheimer served as the committee's chief scientific consultant. The report proposed the creation of the Atomic Development Authority to supervise the production and use of fissile materials, as well as the functioning of all nuclear facilities that could produce nuclear explosives. This proposed Atomic Development Authority would have the right to grant licenses to countries wishing to pursue peaceful nuclear research. The plan depended on Soviet-American cooperation.

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[22] Rabinowitch, "Founding and Father."

[23] United States Department of State Diplomacy In Action, Treaty*, The Acheson-Lilienthal & Baruch Plans, 1946*, http://www.state.gov/r/pa/ho/time/cwr/88100.htm (accessed January 2, 2010).

The report's authors recognized that the Soviet Union was unlikely to give up its veto power in the United Nations Security Council. Moreover, the report made no reference to when the United States would destroy its nuclear arsenal, though it did acknowledge that doing so would be a necessity for a nuclear-weapons-free world. [24]

Figure 2. President Harry S. Truman and Secretary of State Dean Acheson. [25]

As Henry Sokolski has written,

> As long as nuclear weapons gave such a clear offensive advantage to their possessors, inspections and prohibitions against their possible production [with fissile materials] from civilian nuclear facilities would only encourage countries to cheat. The only way around this problem was to prohibit nations from owning *anything* that might help them make a bomb and—as

[24] United States Department of State Diplomacy In Action, Treaty*, The Acheson-Lilienthal & Baruch Plans, 1946.*

[25] The Manhattan Project, An Interactive History, U.S. Department of Energy, http://www.cfo.doe.gov/Me70/manhattan/international_control.htm (accessed January 2, 2010).

the Baruch Plan emphasized—to ensure that the penalties for violating the prohibitions were "swift and condign."[26]

E. THE BARUCH PLAN

According to Edward Ifft,

> The effort to achieve broad acceptance of on-site inspection (OSI) is a story of high diplomacy, creativity, and determination through several U.S. administrations. The ambitious but somewhat naïve Baruch Plan, put forward by the United States in 1946 as a result of the Acheron-Lilienthal Report, was the first great effort to control nuclear weapons.[27]

As Joshua Williams has pointed out,

> The [Baruch] plan sought to establish an International Atomic Development Authority that would own and control all 'dangerous' elements of the nuclear fuel cycle, including all uranium mining, processing, conversion, and enrichment facilities.[28]

As Henry Sokolski has observed,

> The idea was to control nuclear activities and materials so that any nuclear diversions would be noticed well before any nuclear explosive could be built. The international authority's safeguards system had to give "unambiguous and reliable danger signals if a nation takes steps that do or may indicate the beginning of atomic warfare."[29]

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[26] Sokolski, *Best of Intentions*, 15.

[27] Edward Ifft, The Long Road To On-Site Inspection. Arms Control Today 34, no. 9, http://www.proquest.com, 27 (accessed January 6, 2010).

[28] Joshua Williams, *The Quick and the Dead*, Carnegie Endowment for International Peace, http://www.carnegieendowment.org/publications/index.cfm?fa=view&id=17078 (accessed January 2, 2010).

[29] Sokolski, *Best of Intentions*, 15-16.

According to Joshua Williams,

> Moreover, since the objective of the Baruch Plan was not only to restrain the spread of nuclear weapons, but also to prevent an arms race and eliminate the bomb altogether, it proposed that once the Authority could ensure that no other state was able to construct the bomb, the United States would guarantee the elimination of its entire nuclear stockpile.[30]

The authors of the Acheson-Lilienthal Report knew that the main threat with sharing nuclear facilities was that nuclear reactors produced not only power for electricity, but also plutonium, which might be used to make nuclear weapons.[31] Therefore, Henry Sokolski noted,

> They insisted that the plutonium that power reactors produced had so little of the plutonium isotopes optimal for weapons construction (i.e., plutonium 239 and 241) that the material could be considered "denatured," that is, unusable for military purposes.[32]

Although the Acheson-Lilienthal report tried to establish a difference between "safe" and "dangerous" reactors, safe reactors "included nuclear piles optimized for power production (but not for production of plutonium 239 and 241) and very small research reactors that could not produce a weapon's worth of plutonium, even over a period of several years."[33]

The authors concluded that "safe" types of reactors "would be fueled with either low enrichment uranium (which,

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[30] Williams, *The Quick and the Dead.*

[31] Sokolski, *Best of Intentions,* 17.

[32] Ibid.,

[33] Ibid.

unlike highly enriched uranium, lacked sufficient fissile content, that is, high enough concentrations of U235, to make uranium weapons) or a mix of depleted uranium (U238) and denatured plutonium."[34] In contrast, breeder and military production reactors were dangerous for several reasons.

> First, they were optimized for plutonium production. Second, they could be fueled with weapons-usable fissile materials (for example, separated plutonium, thorium, and enriched uranium, which could be directly used to make bombs). Third, they could produce large quantities of the most readily weaponizable kinds of fuel: plutonium 239 and 241.[35]

Joshua Williams concluded,

> The Baruch Plan tried to prevent the balance of terror that later defined the standoff between the United States and the USSR. But it failed, an early victim of the Cold War rivalry. Approved by the UN Atomic Energy Commission on December 31, 1946, the plan was opposed by the Soviet Union in the UN Security Council. Close to achieving his own nuclear bomb, Stalin was not about [to] accept any plan that limited Soviet national sovereignty and that might have locked in, even if only for a short time, America's nuclear advantage. Knowing that the Americans would refuse, the Soviets proposed that any agreement require Washington to disarm prior to some form of the Authority being put in place.[36]

F. ATOMS FOR PEACE

Following the Soviet rejection of the Baruch Plan in 1946, the United States grew wary of the Soviet Union when

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[34] Sokolski, *Best of Intentions,* 17.

[35] Ibid.

[36] Williams, The Quick and the Dead.

it first exploded a nuclear device in 1949. The big question that was on the minds of the leaders of the United States was whether the Soviets would use their nuclear forces against the United States, and if so, when.[37]

With these questions on the minds of officials in Washington, including President Eisenhower, Henry D. Sokolski stated that,

> It was at this point that Eisenhower wrote that he began "to search around for any kind of idea that could bring the world to look at the atomic problem in a broad and intelligent way and still escape the impasse to action created by Russia's intransigence in the matter of mutual or neutral inspection of resources."[38]

Sokolski pointed out how eager Eisenhower was to address the issue of Moscow's aggressiveness.

> Eisenhower shared his thoughts with his special assistant for national security affairs, Robert Cutler: What if the superpowers contributed 'X amount' of fissile material for 'peaceful' purposes, the amount X being a figure the U.S. could handle from its stockpile but that would be difficult for the Soviets to match?[39]

Eisenhower's primary agenda was not entirely to eliminate the Soviet ability to destroy the United States with one powerful blow, but to avoid having to go through the difficult negotiating issues associated with trying to put in place a comprehensive inspection system, a problem that derailed the Baruch Plan.[40]

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[37] Sokolski, *Best of Intentions,* 25.

[38] Ibid., 28.

[39] Ibid.

[40] Ibid.

Although Atomic Energy Commissioner Lewis Strauss had some reservations about Eisenhower's ideas, his concern was that "the plan might backfire with the United States giving too much material and the Soviets too little."[41]

Strauss then reported back to Eisenhower, with findings drawn almost directly from the Panel of Consultants' earlier judgments about the Soviet threat:[42]

> If it could be agreed that as a preliminary step to total disarmament, both parties would in the first instance retain a minimum number of atomic weapons as a means of retaliating against aggressions (but not enough to mount an annihilating surprise attack) . . . it would represent progress in that the threat of war would then be reduced to a degree of injury that could be absorbed without total destruction. The incentive to Russia to attack would be diminished by inability to make such an attack overwhelming and decisive.[43]

Strauss argued that the steps needed to have Washington and Moscow agree on disarmament would be feasible if:

> (1) fissile contributions to the international pool could be steadily increased over time, (2) sufficient confidence could be built to close down all military fissile production plants and restrict mining and refining of uranium and thorium to existing facilities, and (3) Strauss's own plan of guarding the contributed fissile

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[41] Sokolski, *Best of Intentions, 28.*

[42] Ibid., 29.

[43] Lewis Strauss, memorandum for C.D. Jackson, November 6, 1953, quoted in Sokolski, *Best of Intentions*, 29.

> [materials] against theft (dilution of the material in large, remote, underground tanks) was adopted.[44]

Sokolski has highlighted a fact of interest in reference to fissile material:

> With greater demand for contributed fissile material for civilian atomic applications, Strauss reasoned that even greater weapons stockpile reductions would have to be made. This, in turn, would reduce the Soviet military threat and make genuine East-West trust more likely. The plan in its most advanced form (with a military fissile production cut-off) also had the advantage of not requiring international ownership (a Baruch measure that the Soviets opposed) and only limited inspections. Thus, as Jackson, Dulles, Eisenhower, and Strauss later explained it, the plan could well lead to atomic disarmament even though its initial dimensions would be quite modest.[45]

According to Peter Lavoy,

> In a celebrated address to the UN General Assembly on December 8, 1953, Eisenhower heralded a new Atoms for Peace campaign designed to 'hasten the day when fear of the atom will begin to disappear from the minds of people.'[46]

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[44] Sokolski, *Best of Intentions,* 29.

[45] Ibid.

[46] Peter Lavoy, "The Enduring Effects of Atoms for Peace," *Arms Control Today*, December 2003, available at http://www.armscontrol.org/act/2003_12/Lavoy (accessed January 12, 2010), 2.

Figure 3. Atoms for Peace Stamp Washington, D.C. - July 28, 1955, 133,638,850 issued.[47]

In the end, Eisenhower's primary goal was to promote peaceful uses of atomic energy. He hoped that atomic energy could be used to enhance the socio-economic conditions of the world. Eisenhower invited "the governments principally involved" to "make joint contributions from their stockpiles of . . . fissionable materials to an international atomic energy agency . . . set up under the aegis of the United Nations."[48] According to Eisenhower's proposal,

> Mandated to collect, store, and distribute fissile materials, the proposed IAEA [International Atomic Energy Agency] would not have the ownership and punishment powers that doomed the chance for agreement on Baruch's International Atomic Development Agency. Rather,

[47] Southwest Museum of Engineering, Communications and Computation: "The Atoms for Peace Stamp," Washington, D.C. - July 28, 1955, available at: http://www.smecc.org/atomic_energy.htm. (accessed January 4, 2010).

[48] Eisenhower quoted in Peter Lavoy, "The Enduring Effects of Atoms for Peace," *Arms Control Today*, December 2003, available at http://www.armscontrol.org/act/2003_12/Lavoy (accessed January 12, 2010), 2.

> the new agency and 'uranium bank' were intended as simple steps to establish international trust and draw Moscow into a cooperative arms control dialogue.[49]

During the 1950s and 1960s, there were several proposals for the discontinuation of the production of fissile material for military uses. However, with the United States and the Soviet Union each pursuing its own stockpile of nuclear weapons, the production of fissile material continued to flourish.[50]

Guy Roberts stated,

> The last official statement by the U.S. urging a fissile material production cutoff came in 1969 at the Eighteen-Nation Disarmament Committee. The U.S. proposed that IAEA safeguards would apply to fissile material production and would include verification of continued shutdown of production facilities. Despite a lack of U.S. initiative the cutoff idea remained alive in the disarmament literature.[51].

G. PROPOSAL TO CONTROL OR CUTOFF THE PRODUCTION OF FISSILE MATERIALS SINCE THE END OF THE COLD WAR

Since Eisenhower's "Atoms for Peace" speech, experts in nuclear matters have discussed alarming developments in nuclear proliferation. As Guy Roberts has further pointed out,

> For years arms control proponents have advocated halting the production of fissile material (separated plutonium and highly enriched uranium)

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[49] Eisenhower quoted in Peter Lavoy, 3.

[50] Guy Roberts, *This Arms Control Dog Won't Hunt: the Proposed Fissile Material Cut-Off Treaty at the Conference on Disarmament,* USAF Institute for National Security Studies (January 2001)http://www.dtic.mil/cgibin/GetTRDoc?AD=ADA435059&Location=U2&doc=GetTRDoc.pdf (accessed December 1, 2009), 23.

[51] Ibid., 23.

as a means of capping the arsenals of the nuclear-weapon states (NWS). Since the 1970s, countries that have forsworn nuclear weapons have viewed a ban on fissile material production as an important way for the nuclear weapon states to show good faith toward nuclear disarmament—one of their obligations under the Nuclear Nonproliferation Treaty (NPT). In addition to being perceived as a step towards ultimate nuclear disarmament, arms control advocates (and the United States) also see a fissile material production cutoff as an important nonproliferation measure, one that would for the first time bring the undeclared nuclear weapon states—India, Israel, and Pakistan — and other states of proliferation concern into the international nonproliferation regime. Although these states have remained unwilling to sign the NPT, it is argued that they may be persuaded to sign up to a cutoff ban, which would ensure that their nuclear arsenals and material stocks would be frozen at relatively low levels. [52]

One of the stated objectives of the United States' current nonproliferation policy is to cap and eventually reverse the nuclear-weapon programs in these undeclared nuclear-weapon states. Another is to prevent terrorist and other sub-national groups from gaining access to nuclear weapons or to the fissile materials necessary for such weapons. [53]

[52] Roberts, *This Arms Control Dog Won't Hunt,* 23.

[53] Ibid., 1-2.

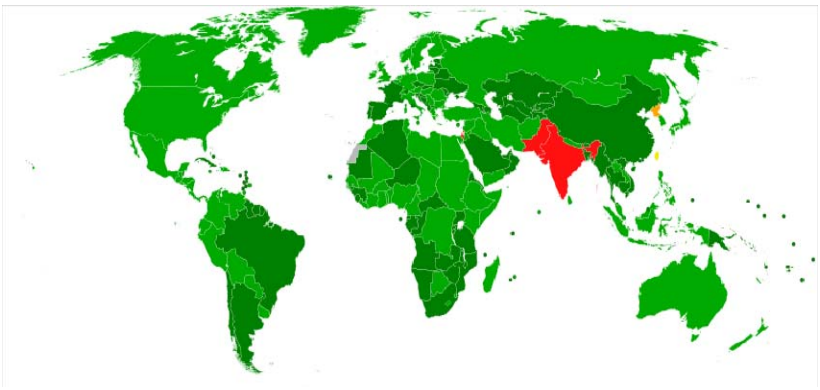

Figure 4. Map of the participants of the Nuclear Proliferation Treaty (NPT).[54]

As the importance of the testing and production of nuclear weapons became evident, the objective of a fissile-material cut-off shifted to a secondary role as the pursuit of a Comprehensive Test Ban Treaty (CTBT) and other measures became the focus. Fear of the pollution caused by nuclear fallout overshadowed the pursuit of the fissile material cutoff proposals.

Although the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), which entered into effect in 1970, was intended to limit the number of nuclear weapons states, India, Israel, and Pakistan never acceded to the NPT and instead acquired nuclear weapons. Moreover, North Korea withdrew from the NPT in 2003 and instead acquired nuclear weapons.[55]

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[54] Global Fissile Material Report 2009, International Panel on Fissile Materials, http://www.fissilematerials.org/ipfm/site_down/gfmr09.pdf (accessed November 17, 2009).

[55] Brian G. Chow, Richard H. Speier, and Gregory S. Jones, *The Proposed Fissile - Material Production Cutoff – Next Steps,* MR-586-1-OSD, (Santa Monica, California, Rand 1995), 1.

In 1995, when India, North Korea, and Pakistan had not yet publicly revealed their status as nuclear weapon states, Brian Chow, Richard H. Speier, and Gregory S. Jones stated that

> One objective of current nonproliferation policy is to cap and eventually reverse the nuclear-weapon programs in these undeclared nuclear-weapon states. Another is to prevent terrorist and other subnational groups from gaining access to nuclear weapons or to sensitive nuclear materials, i.e., plutonium or highly enriched uranium (HEU). Such materials are produced in military and some civilian nuclear programs.[56]
>
> To help achieve these objectives, President Clinton outlined in September 1993 a "framework for U.S. efforts to prevent the proliferation of weapons of mass destruction." This framework included a proposed multilateral convention prohibiting the production of plutonium or HEU unless it is for purposes other than nuclear-weapon production and then only if it is done under international safeguards. The United Nations General Assembly endorsed the proposal within three months subject to the important change that the convention be "nondiscriminatory," that is, that it apply to declared and undeclared nuclear weapon-state states and nonnuclear-weapon states alike.[57]

With regards to the framework that President Clinton outlined for a proposed multilateral convention, Sharon Squassoni, Andrew Demkee, and Jill Marie Parillo wrote,

In response to U.N. General Assembly Resolution 48/75L, the CD [Conference on Disarmament] established a committee in 1995 to begin work on an FMCT. The 66-member

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[56] Chow, Speier, and Jones, *The Proposed Fissile - Material Production Cutoff – Next Steps.*

[57] Ibid.

negotiating body in Geneva agreed by consensus to the so-called “Shannon Mandate,” which called for an “Ad Hoc Committee to negotiate a non-discriminatory, multilateral and internationally and effectively verifiable treaty banning the production of fissile material for nuclear weapons or other nuclear explosive devices.” Canada’s Ambassador Shannon specifically noted that the mandate did not preclude any delegation from raising issues related to the scope of the treaty — whether banning future production, covering existing stocks, or adding management of stocks — during discussions.[58]

Following the conclusion of Comprehensive Test Ban Treaty negotiations in 1996, FMCT appeared to be the next priority, yet CD member states could not agree on a program of work. In late 1998, CD members agreed to establish an Ad Hoc Committee, mostly in reaction to the Indian and Pakistani nuclear tests earlier that year, but the CD was unable to reestablish the Committee in 1999. Within the CD, four basic areas of work — nuclear disarmament, prevention of an arms race in outer space (PAROS), negative security assurances, and a fissile material production cutoff — still compete for priority. Moreover, several states prefer to link progress in one area to progress in another area, which some observers call “hostage-taking.” China, for one, has made its agreement to start FMCT negotiations contingent on the start of PAROS negotiations, and other states have done the same with respect to nuclear

[58] Sharon Squassoni, Andrew Demkee and Jill Marie Parillo, Banning Fissile Material Production for Nuclear Weapons: Prospects for a Treaty (FMCT), CRS Report for Congress, http://fas.org/sgp/crs/nuke/RS22474.pdf (accessed February 17, 2010, 4).

disarmament negotiations. In May 2006, the U.S. delegation told CD members it "sees no need at this time, however, for the negotiation of new multilateral agreements on nuclear disarmament, outer space, or negative security assurances." In June 2006, a U.S. official told the CD that "...there is no — repeat, no — problem in outer space for arms control to solve."[59]

In May 2006, the George W. Bush administration presented the first draft treaty for an FMCT ever advanced by any government. The treaty was entitled "Treaty on the Cessation of Production of Fissile Material for Use In Nuclear Weapons or Other Nuclear Explosive Devices." The treaty began as follows:

> The States Parties to this Treaty (hereinafter referred to as the "Parties"), have agreed as follows: Article I No Party shall, after the entry into force of the Treaty for that Party, produce fissile material for use in nuclear weapons or other nuclear explosive devices, or use any fissile material produced thereafter in nuclear weapons or other nuclear explosive devices.[60]

The white paper on the FMCT made public by the U.S. government stated that:

> The U.S. draft treaty omits verification provisions, consistent with the U.S. position that so-called "effective verification" of an FMCT cannot be achieved. The ability to determine compliance with a high level of confidence is a requirement for effective

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[59] Squassoni, Demkee and Parillo, *Banning Fissile Material Production for Nuclear Weapons: Prospects for a Treaty (FMCT)*, 4).

[60] United States Tables Draft FMCT at Conference on Disarmament, The United States Mission to the United Nation in Geneva, http://geneva.usmission.gov/Press2006/0518DraftFMCT.html (accessed February 18, 2010).

verification. The United States has concluded that, even with extensive verification mechanisms and provisions—so extensive that they could compromise the core national security interests of key signatories, and so costly that many countries would be hesitant to implement them--, we still would not have high confidence in our ability to monitor compliance with an FMCT.

Furthermore, mechanisms and provisions that provide the *appearance* of effective verification without supplying its *reality* could be more dangerous than having *no* explicit provisions for verification. Such mechanisms and provisions could provide a false sense of security, encouraging countries to assume that, because such mechanisms and provisions existed, there would be no need for governments themselves – individually or collectively – to be wary and vigilant against possible violations.

Negotiating an international ban on the future production of fissile material for nuclear weapons will be a difficult enough task, in and of itself. Avoiding time-consuming and, we believe, futile efforts to negotiate "effective" verification measures will expedite action by the CD to conclude a legally binding ban on the production of fissile materials for nuclear weapons and nuclear explosive devices.

The United States believes that only by focusing on realistic objectives can the CD create the conditions necessary for negotiating an FMCT. The successful negotiation of an FMCT in the CD will be both a significant contribution to the global non-proliferation regime and an example of truly effective multilateralism.[61]

[61] United States of America White Paper on Fissile Material Cutoff Treaty, The United States Mission to the United Nation in Geneva, http://geneva.usmission.gov/Press2006/0518WhitePaper.html (accessed September 10, 2009).

While it might have seemed that the United Nations had a consensus on how to curb the production of fissile material for nuclear weapons, Kingston Reif and Madeleine Foley stated,

> On May 18, 2006, the George W. Bush administration submitted a draft FMCT at the Conference on Disarmament (CD) in Geneva that would not contain any verification provision, would ban new production of plutonium and highly enriched uranium for use in nuclear weapons for 15 years, and would enter into force with only the five established nuclear weapon states.[62]

Reif and Foley further stated that they supported the approach advocated by the privately organized International Panel on Fissile Materials (IPFM) and rejected the U.S. approach set forth by the George W. Bush administration in May 2006. According to Reif and Foley,

> The IPFM assumes that verification of a FMCT that covers both future production and pre-existing stocks would be overseen by the IAEA Safeguards Division and cover uranium enrichment facilities, reprocessing facilities, material declared in excess for military use, and HEU for use in naval-propulsion reactor fuel. The Safeguards Division would have to greatly expand its operations to perform the intrusive searches necessary for verification. It would also require a larger budget, a cost that countries may be loath to incur.[63]

The Bush administration's proposal had no verification provisions because of its judgment that an FMCT would not in fact be verifiable. Some critics have argued, however,

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[62] Reif and Foley, *Factsheet on the Fissile Material Cutoff Treaty (FMCT),* 3.

[63] Ibid.

that FMCT verification would be possible. For example, Wade Boese wrote in 2005 that,

> Because the proposed agreement would allow countries to possess and produce plutonium and highly enriched uranium for peaceful purposes, most governments and nongovernmental experts see verification as essential for ensuring that such materials are not surreptitiously diverted to weapons. A verification system would also provide greater assurance that permitted materials are less vulnerable to terrorist theft because they would be subject to international supervision.

The Bush administration's resistance to FMCT verification measures may also stem from the Navy's longtime opposition to allowing international inspectors some oversight of the U.S. naval nuclear propulsion program, which some countries say the treaty should require. When asked whether this was the case in a February [2005] interview, Chris Ford, the principal deputy assistant secretary of state for verification and compliance, replied,

> There are countries that have naval nuclear propulsion programs that would not agree to a treaty that would allow verifiers into all aspects of those programs; countries, plural.[64]

Responses to the May 2006 U.S. proposal for an FMCT revealed a basic polarization on the question of the verifiability of a potential FMCT. Proponents of a verification regime maintain that doubts about the verifiability of such a treaty (such as those expressed by U.S. officials under the George W. Bush administration) are

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[64] Wade Boese, "Shunning the Table," *The American Prospect*, 18 July 2005, available at http://www.prospect.org//cs/articles;jsessionid=aiS9XiEloXocSXo1xA?article=shunning_the_table (accessed February 2, 2010).

politically driven. Skeptics on the verifiability of an FMCT maintain that their doubts are well-founded and that proponents of a verification regime are promising more than can be reliably delivered.

The Bush administration did not hold that there should be no verification of an FMCT but that the treaty should have no verification provisions, and that verification should be via national technical means and methods.

In March 2009, Cole Harvey of the Arms Control Association stated that,

> In recent public statements and congressional hearings, Obama administration officials have indicated that they will reverse Bush-era policies on a number of major arms control issues. Secretary of State Hillary Rodham Clinton and other Obama appointees have said that they will actively pursue ratification of the Comprehensive Test Ban Treaty (CTBT) as well as a new strategic arms agreement with Russia and have revised the U.S. approach to negotiations on a treaty banning the production of fissile material for use in nuclear weapons.[65]

Moreover, Harvey stated that

> Clinton noted in her confirmation hearing that the Obama administration planned to break with its predecessor by restoring U.S. support for a negotiating mandate calling for an eventual FMCT to include international monitoring and verification procedures. In May 2006, the Bush administration proposed a draft FMCT that lacked verification mechanisms, arguing that such provisions would be too expensive, overly intrusive, and unlikely to dissuade determined cheaters . . . Other members of the CD

[65] Cole Harvey, *Obama Sets New Course on Arms Control,* Arms Control Association, http://www.armscontrol.org/act/2009_03/Obama (accessed November 27, 2009).

> [Conference on Disarmament], which conducts its business by consensus, opposed the U.S. stance. Clinton stated in her testimony that abandoning the previous administration's policy is an essential step toward resuming FMCT negotiations.[66]

In January 2009, the Secretary of State-designate, Senator Hillary Clinton, commented on the strong stance the Obama administration was going to take on nuclear proliferation,

> Therefore, while defending against the threat of terrorism, we will also seize the parallel opportunity to get America back in the business of engaging other nations to reduce stockpiles of nuclear weapons. We will work with Russia to secure their agreement to extend essential monitoring and verification provisions of the START treaty before it expires in December 2009, and we will work toward agreements for further reductions in nuclear weapons. We will also work with Russia to take U.S. and Russian missiles off hair-trigger alert, act with urgency to prevent proliferation in North Korea and Iran, secure loose nuclear weapons and materials, and shut down the market for selling them — as Senator Lugar has done for so many years. The Non-Proliferation Treaty is the cornerstone of the nonproliferation regime, and the United States must exercise the leadership needed to shore up the regime. So, we will work with this committee and the Senate toward ratification of the Comprehensive Test Ban Treaty and reviving negotiations on a verifiable Fissile Material Cutoff Treaty.[67]

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[66] Harvey, *Obama Sets New Course,* 1-2.

[67] *Transcript Of Clinton's Confirmation Hearing,* NPR, http://www.npr.org/templates/story/story.php?storyId=99290981 (accessed February 14, 2010), 4.

This strong commitment made by the incoming Secretary of State was soon followed by a more detailed statement by the Assistant Secretary of State-designate for the Bureau of Verification and Compliance, Rose Gottemoeller, in her testimony before the Senate Foreign Relations Committee on March 26, 2009,

> Second, the Administration is committed to negotiating a verifiable Fissile Material Cutoff Treaty (FMCT). The Conference on Disarmament has been deadlocked on the FMCT negotiation issue, with China, Iran, and Pakistan blocking any forward movement. I understand that one element of this deadlock had been the question of whether or not to include international verification provisions. We must use smart diplomacy to break this deadlock and pursue a Fissile Material Cutoff Treaty that includes verification provisions. If confirmed, I intend to focus comprehensively on verification issues affecting both the CTBT and FMCT, drawing on experience and expertise from the VC [Verification and Compliance] Bureau and across the U.S. Government, including the Intelligence Community and the Departments of Energy and Defense.[68]

In April 2009, in a speech in Prague, President Barack Obama announced changes in the U.S. nuclear weapons policy. The president stated,

> And to cut off the building blocks needed for a bomb, the United States will seek a new treaty that verifiably ends the production of fissile materials intended for use in state nuclear weapons. If we are serious about stopping the spread of these weapons, then we should put an

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[68] Testimony by Assistant Secretary of State-designate for the Bureau of Verification and Compliance Rose Gottemoeller, http://foreign.senate.gov/testimony/2009/GottemoellerTestimony090326p.pdf (accessed February 15, 2010), 4.

> end to the dedicated production of weapons-grade materials that create them. That's the first step.[69]

Since the earliest U.S. proposals for controlling the production of fissile material, including the Jeffries Report and Eisenhower's "Atoms for Peace" speech, the United States has sought means to curb the spread of fissile material. The Clinton administration revived the idea of controlling and halting the production of fissile material for weapons. The Obama administration has expressed an intention to pursue policies different from those of the George W. Bush administration on the FMCT. Although there are many issues associated with the FMCT, such as the feasibility and cost of verifying a country's compliance, as well as how a country could protect its secret technology, proposals for such a treaty may move forward in the months and years to come. The issues for U.S. naval nuclear propulsion are addressed in the following chapter.

[69] Remarks by President Barack Obama, The White House, Office of the Press Secretary, http://www.whitehouse.gov/the_press_office/Remarks-By-President-Barack-Obama-In-Prague-As-Delivered (accessed November 28, 2009).

III. ANALYSIS OF HOW DIFFERENT FMCT PROVISIONS COULD AFFECT U.S. NAVAL PROPULSION REACTORS

A. DEFINITIONS OF FISSILE MATERIAL

To appreciate the importance of proposals for a Fissile Material Cut-Off Treaty, one should have an understanding of the materials used to make a nuclear weapon. In a paper entitled *Banning Fissile Material Production for Nuclear Weapons: Prospects for a Treaty (FMCT)*, Sharon Squassoni and her colleagues explained the production of fissile material as follows:

> Such material — plutonium-239, uranium-233, and uranium enriched in the isotope U-235 — is produced several ways. Only the isotope U-235 occurs naturally, but it cannot be used to create a nuclear yield unless it is concentrated significantly. Pu-239 is created in a nuclear reactor by irradiating natural uranium (U-238), which absorbs a neutron to decay into Pu-239. The Pu-239 must then be chemically separated from highly radioactive fission products to be usable in a nuclear weapon. Spent fuel reprocessing plants perform this chemical separation, but it can also be done on a smaller scale, with remote handling and adequate shielding against radiation hazards. U-233 is produced in a reactor by irradiating thorium-232, and also requires chemical separation from fission products. High-enriched uranium (HEU), the ingredient in the first U.S. nuclear bomb, is produced by concentrating the isotope U-235 in an enrichment plant. Although HEU is defined as containing 20% or more U-235, weapons grade HEU generally requires about 90% U-235.[70]

[70] Sharon Squassoni, Andrew Demkee and Jill Marie Parillo, *Banning Fissile Material Production for Nuclear Weapons: Prospects for a Treaty (FMCT)*, CRS Report for Congress, http://fas.org/sgp/crs/nuke/RS22474.pdf, 2 (accessed September 27, 2009).

David S. Jonas of the National Nuclear Security Administration stated,

> Yet some states may wish to limit [the] application [of an FMCT] to U-235 enriched to over 90%. Some believe it should include tritium, americium, and neptunium-237. Tritium, though, does not fission, so there is no valid reason for including it in a FMCT. Since tritium boosts the power of a nuclear weapon, even though it would not be useful without HEU or Pu, some would like to see it in [an] FMCT. Tritium must not be included since it would clearly be unacceptable to the NWS.[71]

The United States draft of the FMCT, proposed by the George W. Bush administration, defines fissile materials, according to David S. Jonas, as,

> Pu except Pu where the isotopic composition includes 80% or greater Pu-238 and uranium containing 20% or greater enrichment in U-233 or U-235.[72]

[71] David S. Jonas, *The New U.S. Approach to the Fissile Material Cutoff Treaty: Will Deletion of a Verification Regimes Provide a Way Out of the Wilderness?)*, Selected Works, http://works.bepress.com/david_jonas/,649. (accessed January 2, 2010).

[72] Ibid., 650.

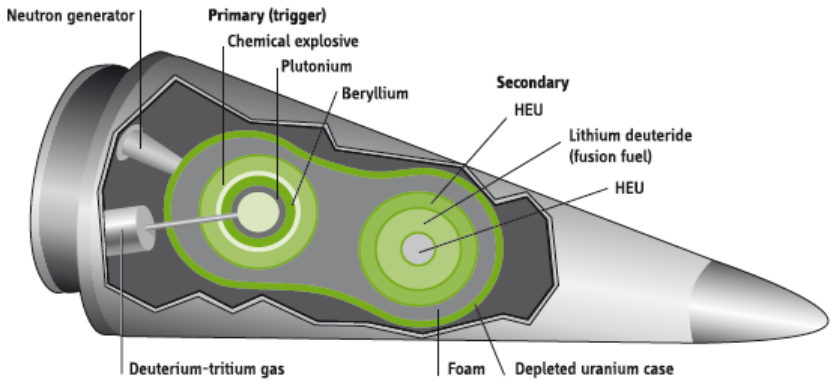

Figure 5. Cut-away of a nuclear warhead which contains electronic and nuclear explosives, often referred to as the "physical package."[73]

B. THE RAMIFICATIONS OF "LOST" HEU

William C. Potter has drawn attention to the "special dangers" of HEU.

> In a pre-9/11 environment in which states constituted the main nuclear proliferation challenge, it made sense to treat HEU and plutonium as roughly equivalent dangers. Today, however, in a world where non-state actors pose greater threats in terms of the likely use of nuclear explosives, more effort should be invested in rapidly securing, consolidating, reducing, and eliminating global stocks of HEU. The principal reason for this needed shift in emphasis, which is not yet evident in the

[73] The International Panel on Fissile Materials, Global Fissile Material Report 2009, *A Path to Nuclear Disarmament*, http://www.fissilematerials.org/ipfm/pages_us_en/fmct/fmct/fmct.php. (accessed January 12, 2010) 68.

> policies of most national governments, is the much easier task for terrorists of building an HEU-based nuclear explosive.[74]
>
> The most basic type of nuclear weapon, and the simplest to design and build, is a ‘‘gun-type’’ device. As its name implies, it consists of a gun barrel in which a projectile of HEU is fired into another stationary piece or ‘‘target’’ of HEU. Each piece of HEU is subcritical and by itself cannot sustain an explosive chain reaction. Once combined, however, they form a supercritical mass leading to a nuclear explosion. Although weapon-grade uranium enriched to over 90 percent of the isotope uranium-235 (U-235) is the most effective material for a gun-type explosive, a nuclear detonation can be produced with lower levels of enrichment. The Hiroshima bomb, for example, used about 60 kilograms (kg) of uranium enriched to 80 percent. Terrorists would probably need at least 40 kg of weapon-grade or near-weapon-grade HEU to have reasonable confidence that an IND [improvised nuclear device] would work.[75]

C. DIFFERING VIEWS ON FMCT PROVISIONS

There are differing views as to what an FMCT should limit and what its verification requirements should be. The FMCT proposed by the U.S. government in May 2006 would not affect the United States Navy’s nuclear propulsion program at all. In contrast, the FMCT proposed by the International Panel on Fissile Materials (IPFM) would require special arrangements to verify that the HEU used as fuel in U.S. naval reactors is not used for weapons. Some other FMCT-related proposals could affect the nature of the

[74] William C. Potter, *Nuclear Terrorism and the Global Politics of Civilian HEU Elimination,* The Nonproliferation Review, http://pdfserve.informaworld.com/6345_793890206_793982545.pdf (accessed January 10, 2010), 140.

[75] Ibid.

verification process, as well as naval propulsion reactor designs, and could lead to changes in current and future nuclear-powered vessels.

D. IS THERE A NEED FOR HIGHLY ENRICHED URANIUM FOR NAVAL REACTORS?

Chunyan Ma and Frank von Hippel are quoted extensively in this chapter due to their dedicated efforts to identify approaches to more comprehensive FMCT regimes. Specifically, they have argued that an FMCT regime could be devised to cut off the production of fissile material intended for naval propulsion, as well as for nuclear weapons and other nuclear explosives.

In an article published in 2001, Chunyan Ma and Frank von Hippel, a researcher in China's Defense Science and Technology Information Center and a professor at Princeton University respectively, wrote,

> Currently, the United States and the United Kingdom use 'weapon-grade' uranium containing more than 93 percent uranium-235 (U-235) to fuel their naval reactors, and Russia uses HEU containing more than the 20 percent U-235, defined by international agreement to be the threshold for direct weapons-usability. France has fueled some of its submarines with HEU but has decided to shift to low-enriched uranium (LEU) containing less than 20 percent U-235. China reportedly uses LEU fuel. In the past, both the United States and the Soviet Union built HEU-fueled nuclear reactors for other military purposes.76

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76 Chuyan Ma and Frank N. von Hippel, "Ending the Production of Highly Enriched Uranium for Naval Reactors," *The Non-Proliferation Review*, http://cns.miis.edu/npr/pdfs/81mahip.pdf (accessed August 25, 2009),87.

According to Morten Bremer Maerli of the Norwegian Institute of International Affairs,

> No official figures exist on the U.S. stockpiles of HEU for naval purposes or material destined for future naval consumption. Estimates indicate an overall consumption of HEU in U.S. reactors since the dawn of nuclear propulsion of approximately 120 tons — some 12% of the total U.S. HEU production of nearly 1,000 tons.77

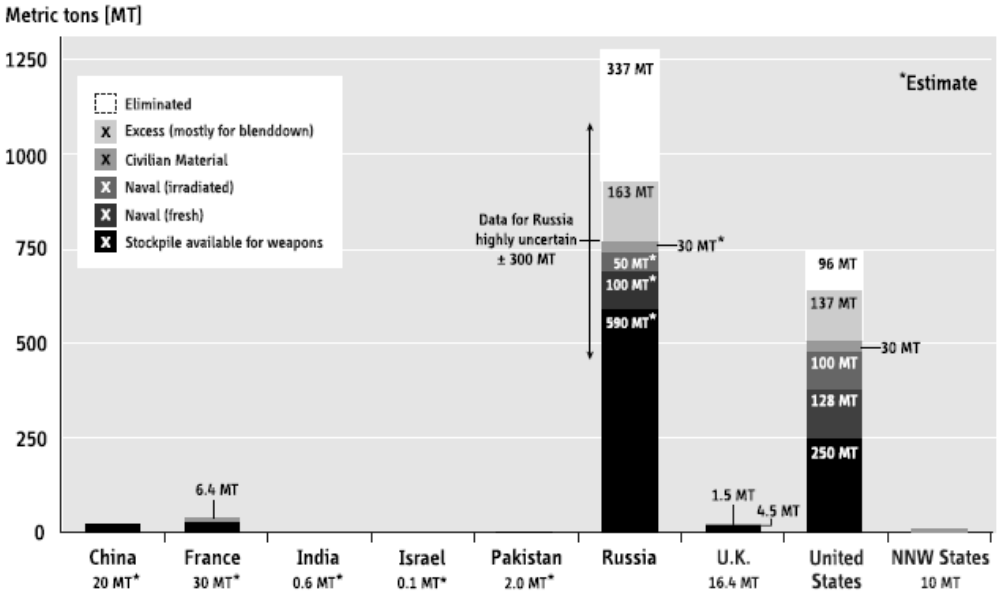

Table 1. National stocks of highly enriched uranium in mid 2008.[78]

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77 Morten Bremer Maerli, "Components of Naval Nuclear Fuel Transparency," *NATO-EAPC Fellowship Report*, http://www.nato.int/acad/fellow/99-01/maerli.pdf (accessed November 21,2009), 11.

78 Alexander Glaser and Zia Mia, "Fissile Material Stockpiles and Production, 2008", *Science and Global Security*, http://www.informaworld.com/smpp/content~content=a906580061&db=allpdf (accessed January 19, 2010), 58.

Scholars such as Chunyan Ma and Frank von Hippel have argued that the United States *could* comply with *their* proposed version of an FMCT by banning not only the production of fissile materials for weapons, but also by extending it to any weapon-usable fissile materials for *any* military use, including naval propulsion reactors.[79]

Chunyan Ma and Frank von Hippel have further stated that countries such as the United States, the United Kingdom, and Russia, currently employ naval reactors that use HEU. These countries, according to Ma and von Hippel, can enjoy the luxury of decades of planning for a transition to LEU. While in this "transition" period, they have asserted, these states will have the time needed to design the "next generation" of LEU-powered submarines. If the FMCT is to be upheld and honored by all parties, Ma and von Hippel maintain, countries joining in the nuclear navy propulsion "club" would have to fuel their naval reactors with LEU.[80]

According to Chunyan Ma and Frank von Hippel,

> The world's nuclear fleet currently contains 170 submarines and ships, including six icebreakers and an Arctic transport operated by Russia. This is about half the size of the nuclear-powered fleet deployed at the end of the Cold War.[81]

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[79] Chuyan Ma and Frank N. von Hippel, "Ending the Production of Highly Enriched Uranium for Naval Reactors," *The Non-Proliferation Review*, http://cns.miis.edu/npr/pdfs/81mahip.pdf (accessed August 25, 2009), 87.

[80] Ibid.

[81] Ibid., 89.

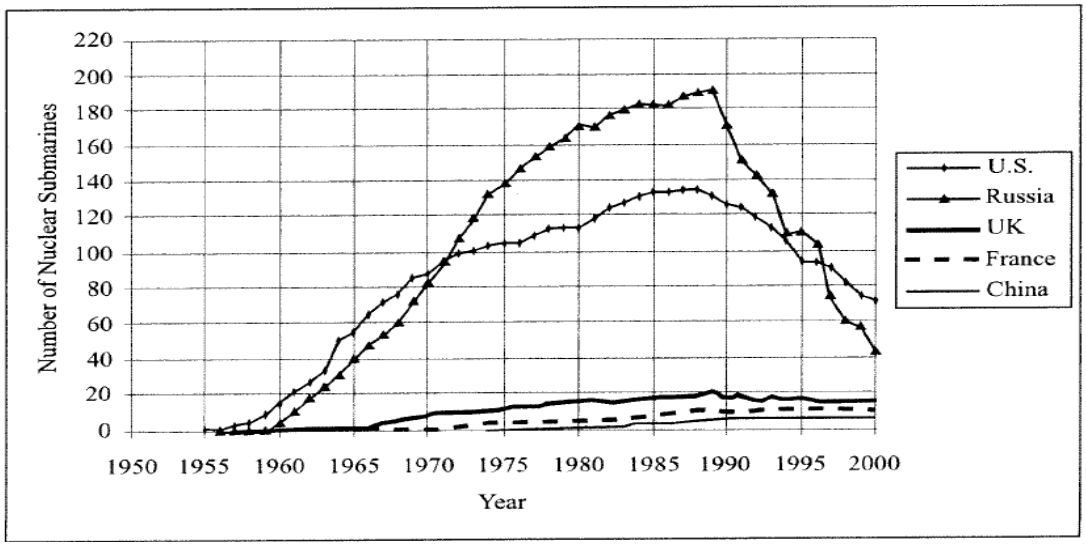

Table 2. Evolution of the World's Nuclear Submarine Fleets.[82]

Ma and von Hippel have noted that the United States has consistently increased the nuclear core lifetime for a submarine from about two years (the first U.S. nuclear-powered submarine, the *Nautilus*), to a 33-year life for the new Virginia-class submarine:

Current cores in the Nimitz-class aircraft carriers, Los Angeles-class attack submarine and Ohio-class ballistic missile submarine last an average of about 20 years. Efforts are continuing to develop lifetime cores for new aircraft carriers (50 years) and the next generation ballistic missile submarine (40 years).[83]

Ma and von Hippel maintain:

> During the 1980s, the U.S. Navy ordered four to five metric tons of U-235 in HEU per year. However, the size of the US nuclear submarine

[82] Ma and von Hippel, "Ending the Production of Highly Enriched Uranium for Naval Reactors," 89.

[83] Ibid.

fleet has declined from 139 in 1990 to 73 (18 ballistic missile submarines and 55 attack submarines) in 2000 and the number of naval propulsion reactors has decreased to 97. Given that improved uranium efficiency is likely to have contributed to the greater longevity of the new reactors, the annual requirement for American nuclear submarines today is probably very roughly two tons [of] U-235. For a nominal core life of 20 years, this would imply an average of five cores per year containing about 400 kilograms (kg) of U-235 each.[84]

A number of authors estimate that the total stockpile of U-235 in U.S. HEU was approximately 600 tons. This total has since been reduced by 174 tons of HEU (almost all lower than weapon-grade) being declared excess to military needs. However, much of the weapon-grade uranium recovered from excess nuclear weapons is being placed in a reserve for future naval reactor use. As a result, the United States has enough HEU stockpiled to fuel its nuclear ships at the current rate for "many decades."[85]

[84] Ma and von Hippel, "Ending the Production of Highly Enriched Uranium for Naval Reactors," 92.

[85] Ibid., 89.

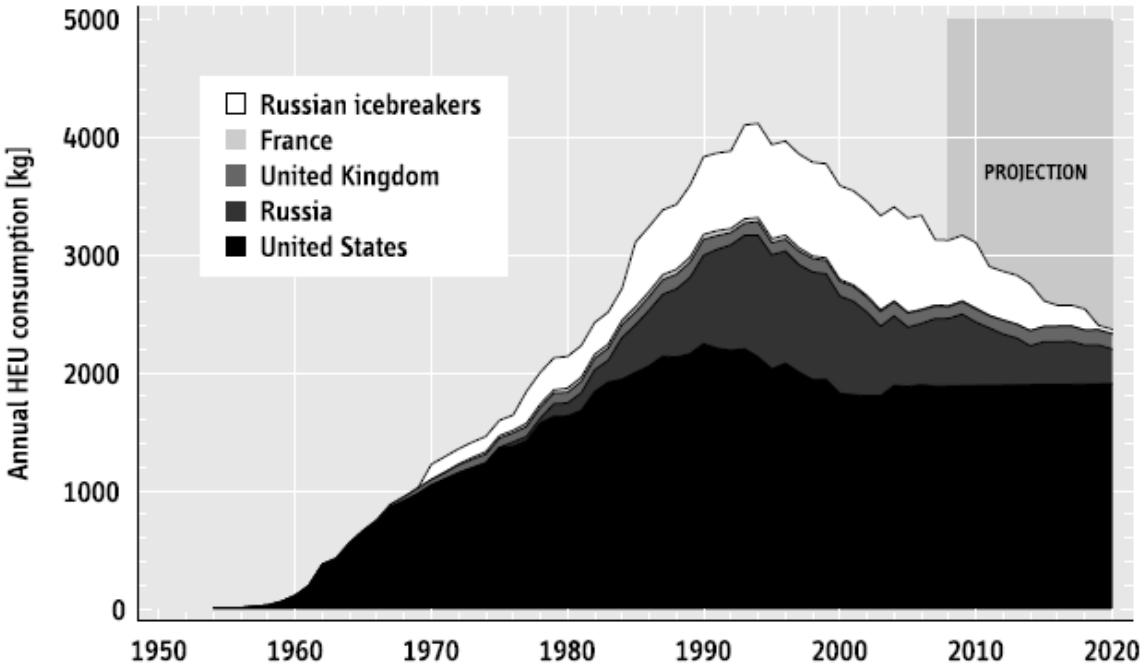

Table 3. Estimated annual HEU consumption in naval vessels.[86]

Figure 8 suggests that the use of HEU in naval vessels peaked during the early 1990s (coincident with the end of the Cold War), and that it has dramatically decreased in subsequent years. Alexander Glaser and Zia Mian of Princeton University have reached findings similar to those of Chuyan Ma and von Hippel. According to Glaser and Mian,

> The United States appears to be committed to maintaining its reliance on nuclear propulsion for its aircraft carriers and submarines, and possibly expanding it to include nuclear-powered cruisers. The 128 tons of HEU that the United States has set aside for military naval nuclear propulsion would be sufficient to fuel its surface ships and submarines for 40–60 years. In

[86] Alexander Glaser and Zia Mian, "Fissile Material Stockpiles and Production, 2008", *Science and Global Security*, http://www.informaworld.com/smpp/content~content=a906580061&db=allpdf (accessed January 19, 2010), 58.

> 2008, the U.S. Senate required the navy to study the possibility of LEU fuel for future nuclear powered ships.[87]

It is clear that the United States will be able to sustain its submarines and aircraft carriers with HEU for several decades. However, should the United States convert to low enriched uranium (LEU) as reactor fuel, Ma and von Hippel argue, it could then meet the proposed requirements of the FMCT as delineated by those who advocate extending the FMCT to the production of fissile material for naval propulsion. Ma and von Hippel make this argument by citing the French example.

> Different classes and generations of French submarines use different fuel enrichments. The first three of France's first-generation (1970s) Redoutable-class ballistic missile submarines were reportedly fueled by LEU. However, the fourth and fifth ballistic missile submarines in this series were shifted to HEU. France's first generation of attack submarines, the Rubis class, and a second generation of ballistic missile submarines, the Triomphante class, returned to LEU fuel. . . In the wake of France's decision to end the production of HEU, its intention appears to be to stay with LEU enriched to less than 10 percent.
>
> Based on its current plans, in 2015 France is expected to have the same number of nuclear-powered submarines as it has in January 2001: four ballistic-missile submarines and six attack submarines — plus one nuclear-powered aircraft carrier.[88]

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[87] Glaser and Mian, "Fissile Material Stockpiles and Production, 2008," 61.

[88] Ma and von Hippel, "Ending the Production of Highly Enriched Uranium for Naval Reactors," 92-93.

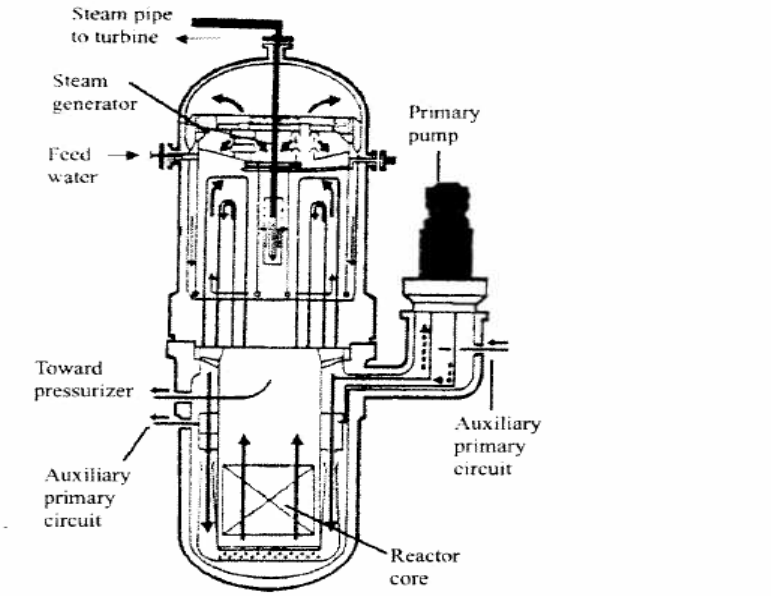

Figure 6. Integrated Reactor and Steam Generator in France's Rubis Nuclear-Powered Submarine.[89]

Clearly, Ma and von Hippel regard converting from HEU to LEU as reactor fuel desirable; however, the United States Navy does not view it as such. In a 1995 report to the U.S. Congress, the Director of the Office of Naval Nuclear Propulsion (ONNP) stated that

> [U.S.] Naval reactor cores have evolved in compactness to the point where the maximum amount of uranium is packed into the smallest volume, and the only way to make more volume available for uranium would be to remove cladding, structure or coolant. In other words, no more uranium could be packed into a modern long-lived core without degrading the structural integrity or cooling of the fuel elements.[90]

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[89] Ma and von Hippel, "Ending the Production of Highly Enriched Uranium for Naval Reactors," 94.

[90] Director, Naval Nuclear Propulsion, *Report on Use of Low Enriched Uranium in Naval Nuclear Propulsion*, 1995, 8, quoted in Ma and von Hippel, 93.

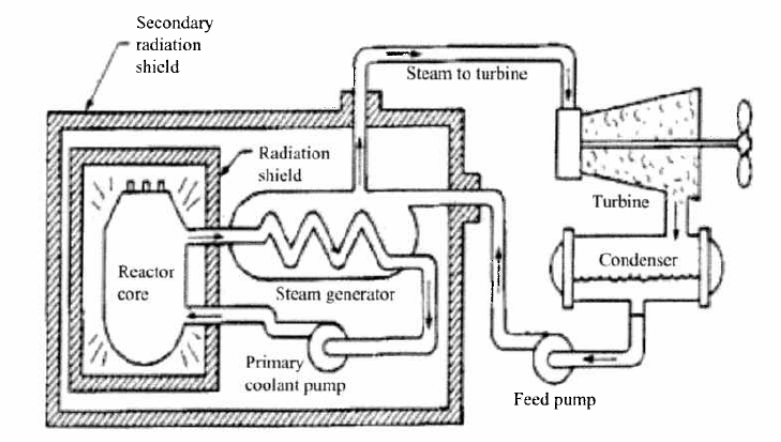

Figure 7. Separate Reactor and Steam-Generator in U.S. Nuclear Submarines.[91]

The Director of the ONNP described the findings of two alternatives for using uranium enriched to 20 percent for reactor cores:

> 1. *Keep the size of the cores fixed and replace the weapon-grade uranium with an equal amount of LEU.* This would reduce the amount of U-235 in the cores by a factor of 4.7. According to the ONNP report, such a reduction would reduce the core life for the Virginia-class submarine from 33 to 7.5 years, and, for Trident-class submarines and Nimitz-class aircraft carriers equipped with 45-year cores, to 14 and 10.4 years respectively.
>
> 2. *Increase the volume and hence the amount of uranium until the same core life can be achieved with LEU.* The ONNP report states that the volume of the core would have to be increased by approximately a factor of three. This is less than the ratio of 4.7 between the amount of 20-percent LEU and weapon-grade uranium containing 93 percent U-235 because some of the uranium-238 (U-238) added to the fuel would be converted by neutron absorption to fissile plutonium fuel.

[91] Director, Naval Nuclear Propulsion, *Report on Use of Low Enriched Uranium in Naval Nuclear Propulsion*, 1995, 8, quoted in Ma and von Hippel, 94.

> Also, the larger reactor would have the same power as the smaller reactor and therefore would not require proportionally more cooling.[92]

In another article, von Hippel wrote,

> Converting U.S. and U.K. naval reactors to LEU would be more difficult [than would be the case for some countries' naval reactors]. French and Russian reactors are refueled every 5 to 10 years. The U.S. and U.K., in an effort to avoid refueling shutdowns, are moving to reactor cores designed to last the lifetime of the ship—up to 45 years. In a 1995 report to Congress, the Department of Energy's Office of Naval Nuclear Propulsion asserted that the density of the uranium in its naval-reactor fuel could not be increased and that, therefore, if the core lifetimes were to be preserved, conversion to LEU would require three times larger and proportionately more costly cores. There has been no independent peer review of this conclusion. Since naval-reactor fuel designs are classified, such peer review would have to be done on a classified basis.[93]

E. VERIFICATION OF THE NAVAL NUCLEAR PROGRAM UNDER THE PROPOSED FMCT

One of the most important questions associated with an FMCT is how to verify a country's compliance. As Guy Roberts pointed out,

> During full-fledged negotiations, the verification aspect of a fissile material cutoff agreement is very likely to prove one of the most politically difficult and, in varying degrees, technically complex issues. Two questions that

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[92] Chuyan Ma and Frank N. von Hippel, "Ending the Production of Highly Enriched Uranium for Naval Reactors, 95.

[93] Frank N. von Hippel, "A Comprehensive Approach to Elimination of HEU from All Nuclear-Reactor Fuel Cycles," Princeton University, *Program on Science & Global Security*, http://www.princeton.edu/sgs/publications/sgs/pdf/12-3_von%20Hippel_SGS_137-164.pdf (accessed January 20, 2010), 150–151.

> immediately stand out, which are closely related but separate are: what should be the role of the IAEA in cutoff verification? And what overall verification approach or architecture should guide crafting of a cutoff verification regime? In deciding whether to follow a comprehensive or streamlined approach towards verification, efforts must be made to contain perceptions of unfair discrimination between non-nuclear and nuclear countries as well as to avoid major inconsistencies between traditional IAEA verification and that of a cutoff convention.[94]

However, there are countries, including the United States, that go to great lengths to protect their naval nuclear propulsion programs. According to Morten Bremer Maerli,

> All the five declared nuclear weapon states under the Non-Proliferation Treaty possess nuclear-propelled submarines. However, as nuclear weapon states, they are all exempted from international (IAEA) safeguards and other monitoring activities. Sensitivity issues and the strategic importance of nuclear submarines have led the nuclear weapon states to maintain a high degree of secrecy around their own nuclear naval operations. Very little is officially known about U.S. and Russian submarine nuclear fuel designs, production technology, operational data and naval fuel stocks.[95]

Although it would be extremely difficult for these states with nuclear-powered submarines to open their programs to international inspection, David S. Jonas emphasized that some observers find merit in programs to

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[94] Guy Roberts, *This Arms Control Dog Won't Hunt: the Proposed Fissile Material Cut-Off Treaty at the Conference on Disarmament,* 35.

[95] Morten Bremer Maerli, *Components of Naval Nuclear Fuel Transparency*, *NATO-EAPC Fellowship Report*, http://www.nato.int/acad/fellow/99-01/maerli.pdf (accessed November 21, 2009), 11.

verify the “shape, composition and mass” of the “pits” of nuclear weapons as a potential precedent for verifying reactor fuels.

> While the Bush Administration has concluded that it would be practically impossible to make a FMCT effectively verifiable, others, including John Carlson of the Australian Safeguards and Nonproliferation Office, maintain that it would be possible. Carlson points to the example of the Trilateral Initiative between the United States, Russia, and the IAEA, which has demonstrated that it can be practical to verify fissile material of sensitive shape, composition and mass. He suggests a similar mechanism for verification of naval fuels. Of course there are great differences in the scale of operations between the verification of “pits” from nuclear weapons under the Trilateral Initiative, and the verification of naval fuels. Additionally, the Trilateral Initiative involved nuclear weapon pits in storage containers in known locations. A truly verifiable FMCT would have to be able to detect undeclared, clandestine enrichment and reprocessing activities.[96]
>
> Carlson concedes that it would be impractical to have an FMCT verification regime of wide scope, which would include all nuclear facilities and materials except existing stocks and nonproscribed military activities such as naval propulsion. The other option, which he recommends, is the “focused” approach which would only concentrate on the most proliferation sensitive fissile material production facilities—specifically enrichment and reprocessing facilities.[97]

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[96] David S. Jonas, *The New U.S. Approach to the Fissile Material Cutoff Treaty: Will Deletion of a Verification Regimes Provide a Way Out of the Wilderness?)*, Selected Works, http://works.bepress.com/david_jonas/, 656-657 (accessed January 2, 2010).

[97] Ibid., 657.

Guy Roberts stressed the importance of the financial costs of the verification of stocks of fissile materials and related production sites.

> A 1995 IAEA comparison of the annual cost of full verification of separated fissile material and facilities capable of producing such materials was $90 million, only one-third less than the estimate of $140 million per year for full safeguards on all civilian facilities in the NWS. While most agree that in the event there is an FMCT the IAEA is the ideal agency to serve as the verification instrument, unfortunately, the IAEA, in its present financial condition, will be unable to fulfill any such role unless the states parties agree to full funding to support these additional costs."[98]
>
> The safeguards operations budget of the IAEA in 2000 was over $80 million. It would be almost tripled to $200 million/year for the most costly comprehensive FMCT verification approach considered in the 1995 IAEA working paper. This $140 million increase would be tiny, however, in comparison with the operational cost savings realized by the NWS as a result of shutting down their fissile-material production complexes. From 1984 through 1993, the United States alone spent about $2 billion per year on plutonium production for weapons. From 1954 through 1963, before the
>
> United States ended the production of HEU for weapons and began shutting down many of its plutonium-production reactors, the annual American rate of expenditure for the production of fissile materials for weapons averaged about $7.billion.[99]

[98] Guy Roberts, *This Arms Control Dog Won't Hunt: the Proposed Fissile Material Cut-Off Treaty at the Conference on Disarmament,* 40.

[99] Ibid., 40–41.

The building of a regime that would have the necessary financial support, as well as the capability to verify a country's capacity to produce fissile materials, is a distant prospect. The U.S. Navy has adopted a prudent and cautious approach. According to Morten Bremer Maerli,

> In fact, the U.S. Navy has been proceeding with extreme caution, keeping in military reserve *all* the fissile material usable for naval propulsion. The low proportion of higher enrichment levels in HEU declared excess to national security needs stems from U.S. Navy insistence that such material be reserved for its possible future needs. With the exception of the first 10 tons declared excess, all of the HEU that the U.S. has declared excess failed to meet the specifications for use in naval fuel. Of the 174.3 excess tons of HEU, about 33 tons are enriched over 92%, and 142 tons are enriched between 20 to 92%.[100]
>
> Moreover, the pledges given by the U.S. that no fuel ever put under international safeguards will be withdrawn for military purposes do not apply to the Navy. It could withdraw HEU that has been declared excess to national security needs and put under safeguards, to use it as naval reactor fuel. However, the Navy has never evoked its unique pullback option. The U.S. Navy plans well and probably does not intend to use currently safeguarded excess material for its programs; moreover, attempting to do so would [face] a steep uphill political climb. The policy of withdrawal allowance should undergo review, as it is likely to undermine the evolving norm of irreversibility in nuclear arms control.[101]

Chunyan Ma, Frank von Hippel, and certain other scholars have argued that future United States naval nuclear propulsion reactors could power vessels with LEU.

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[100] Maerli, *Components of Naval Nuclear Fuel Transparency*.

[101] Ibid., 12.

However, despite their recommendations, it will probably be at least fifty years or more before the U.S. Navy begins to operate nuclear-powered vessels with LEU. The following chapter discusses recommendations on the appropriate policy for the United States concerning arrangements relevant to the how the U.S. Navy might fare under a possible FMCT.

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IV. CONCLUSIONS

Although states such as Brazil and France have converted their nuclear-powered submarines from HEU to LEU, the United States Navy does not currently see such a conversion as a viable option. The United States Navy also has concerns about verification under a possible FMCT. As noted in the previous chapter,

> All the five declared nuclear weapon states under the Non-Proliferation Treaty possess nuclear-propelled submarines. However, as nuclear weapon states, they are all exempted from international (IAEA) safeguards and other monitoring activities. Sensitivity issues and the strategic importance of nuclear submarines have led the nuclear weapon states to maintain a high degree of secrecy around their own nuclear naval operations. Very little is officially known about U.S. and Russian submarine nuclear fuel designs, production technology, operational data and naval fuel stocks.[102]

According to Glaser and Mian,

> The 128 tons of HEU that the United States has set aside for military naval nuclear propulsion would be sufficient to fuel its surface ships and submarines for 40–60 years.[103]

Vessels that will be built in the future will have the technology to be in service at least fifty years. For example, the *U.S.S. Enterprise* (CVN 65), the world's first

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[102] Maerli, *Components of Naval Nuclear Fuel Transparency, NATO-EAPC Fellowship Report*),11.

[103] Glaser and Mian, "Fissile Material Stockpiles and Production, 2008," 61.

nuclear powered aircraft carrier, and the oldest, is scheduled to be decommissioned in 2013 after 51 years of service.

Should the proposed FMCT take effect, the United States Navy can continue to build submarines fueled by HEU while designing a prototype submarine (similar to the Deep Submergence Vessel NR-1)[104] powered by a nuclear reactor that is fueled with LEU and studying its performance. Such studies can include the endurance and sustainment of the submarine, the re-fueling intervals of the LEU fuel, as well as the cost analysis of powering the submarines with LEU fuel.

As for the verification process, the ships and submarines of states that already use HEU as reactor fuel would not have to be verified as long as the treaty stated that its provisions would not apply to them.

The draft FMCT that was prepared by the non-governmental International Panel on Fissile Materials (IPFM) in 2009 suggested that the IAEA would be the ideal organization to support an FMCT, as this might ease the concerns of the United States over verification of its nuclear program:

> The IPFM believes that an FM(C)T could be verified as effectively as the Nonproliferation Treaty. Our draft treaty therefore requires verification. As with the NPT, the draft treaty calls upon the IAEA to implement the needed verification arrangements, but these arrangements are not spelled out in the treaty itself. The

[104] United States Navy, Fact File "NR 1 Deep Submergence Craft," May 24, 1999, available at: http://web.archive.org/web/20030429014652/www.chinfo.navy.mil/navpalib/factfile/ships/ship-nr1.html. (accessed February 4, 2010).

> Panel has developed specific ideas on verification, however. Some of these have been laid out in our *Global Fissile Material Report 2008(GFMR08)*.[105]
>
> There are compelling reasons for the IAEA to take on responsibility for verification. The IAEA has extensive experience in inspecting nuclear installations and nuclear materials, including in the NPT nuclear-weapon states under their voluntary safeguards agreements. The obligations of nuclear-weapon states under the FM(C)T will overlap strongly with the obligations of non-weapon states under the NPT and will become more similar as nuclear disarmament proceeds. The IAEA, advised by national experts, might begin the development of a model protocol in advance of the completion of an FM(C)T.[106]
>
> To undertake the new responsibilities, the IAEA's Safeguards Division will have to grow substantially. Additional funding will be required for such an expansion but it will be miniscule in comparison, for example, with the cost either of nuclear-weapon programs or of the production of nuclear energy.[107]

The IPFM has suggested that entrusting the IAEA with the responsibility of performing verification might end the stalemate with the United States, and lead Washington to change its policy regarding a proposed FMCT, since it is already a party to the NPT. However, the United States government has historically expressed some uncertainties and reservations about FMCT verification, including with IAEA involvement.

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[105] International Panel on Fissile Materials, *A Fissile Material (Cutoff- Treaty): A Treaty Banning the Production of Fissile Materials for Nuclear Weapons or Other Nuclear Explosive Devices)*, 2 September 2009, http://www.fissilematerials.org/ipfm/site_down/fmct-ipfm-sep2009.pdf p. 4; italics in the original, (accessed February 2, 2010).

[106] Ibid.

[107] Ibid.

The following considerations are some of the key points concerning how a proposed FMCT might ultimately affect U.S. interests concerning nuclear naval propulsion:

- The likelihood of political agreement on an FMCT is very low.
- The conclusion of an FMCT encompassing fissile materials for naval propulsion is even more remote. None of the P-5 countries would accept such an FMCT, nor would Brazil or any other country interested in naval nuclear propulsion.
- The establishment of transparency and verification measures is not equivalent to actual verifiability. The practical feasibility of the reliable verification of all weapons-grade enrichment, including that involved in the production of fissile material for naval propulsion reactors, has not been demonstrated. Governments will always retain an ability to resume production, even if they have agreed to an FMCT.
- The verification of existing stocks would require highly intrusive measures. Existing stocks might function as a reservoir into which a state might pour new production. An obvious means of cheating would be to keep existing stocks at a constant level while, in fact, producing new quantities of fissile material.
- The United States government should not, and probably will not, endorse an FMCT that would affect the production of fissile materials for naval nuclear propulsion. The U.S. government has

consistently held that an FMCT should be limited to prohibiting the production of fissile materials for weapons and other nuclear explosives.

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