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# Nuclear Proliferation: How the United States Accommodates Nuclear Threat

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## *Executive Summary*

In April of 2009, President Barack Obama stated "we must ensure that terrorists never acquire a nuclear weapon. This is the most immediate and extreme threat to global security." Substantial actions will be required to prevent proliferation in a global community where nuclear energy is being made readily available to countries all around the world. Nonproliferation cannot be achieved through technical means alone; significant political measures are required in order to minimize the risk.

The materials used to create nuclear weapons are widely acknowledged to be beyond the capabilities of terrorist groups to produce. However, with enough of this material in hand, some well-organized groups could make at least a crude nuclear bomb powerful enough to devastate an entire city. There is enough of this material worldwide, either separated or still inside nuclear warheads, to make roughly 200,000 nuclear weapons. A fraction of one percent of these stockpiles ending up in the wrong hands could cause a global catastrophe. By removing all nuclear materials from vulnerable locations, increasing effective security measures for the remaining sites, and working to eliminate the material worldwide, the danger of nuclear terrorism can be greatly reduced.

The principal political elements of the nonproliferation effort are contained in the Nuclear Non-Proliferation Treaty, which recognizes five nations as "nuclear weapons states" and specifies that non-nuclear weapons states must agree to never acquire nuclear weaponry. In exchange, the nuclear weapons states agree to share the benefits of peaceful nuclear technology. It is acknowledged that there are basic deficiencies present in this treaty. Members can withdraw on three months' notice, it by and large restricts inspections from the International Atomic Energy Agency, and it has almost no power to enforce its provisions. Additionally, there are four nations who are not members of this treaty who have or are believed to have nuclear weapons programs. Actions from the United States and international community are required in order to combat the deficiencies presented in this treaty.

In addition to international treaties, the United States has many domestic policies which reduce the nuclear threat. These initiatives, among other things, seek to consolidate the number of vulnerable locations of nuclear material, increase security at the remaining locations, and convert the materials into more peaceful forms. While great strides have been made to reduce the proliferation threat, there is much yet to be accomplished in this manner, and the ways in which to accomplish the remaining tasks remain up in there air.

This study analyzes the history of this issue, gives a brief technical, political and historical background, and discusses the key conflicts standing in the way of minimizing nuclear proliferation. It concludes by discussing several viable alternatives that the United States and international community have at their disposal in order to make progress in reducing the threat. Finally, this author forms a series of recommendation which he sees will present an effective and comprehensive strategy to promote peaceful uses of nuclear energy without the dangers of nuclear terrorism.

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*Introduction of Problem*

In April of 2009, President Barack Obama stated "we must ensure that terrorists never acquire a nuclear weapon. This is the most immediate and extreme threat to global security." Drawing upon multiple security breaches and theft of nuclear weapons material, the President announced "a new international effort to secure all vulnerable nuclear material around the world within four years."[1] Great progress has been achieved since this declaration in reducing the nuclear terrorism threat, but the mission of securing all vulnerable material is not yet achieved. This paper will evaluate the threat of nuclear proliferation, the actions of the United States to reduce that threat and how the country can progress to eliminate the threat and promote peaceful use of nuclear energy.

Even if nuclear power were not likely to become a larger industry, substantial actions would be needed to strengthen the global effort to prevent the spread of nuclear weapons. Even more substantial actions will be required to prevent proliferation in a global community where nuclear energy is being made readily available to countries all around the world. Widespread proliferation would undermine if not eliminate public support for nuclear energy. Therefore, limiting proliferation is essential if the United States and the rest of the world continue to rely on nuclear power. Nonproliferation cannot be achieved through technical means alone; significant political measures are required in order to minimize the risk.[2] In order to minimize or eliminate the nuclear threat, an understanding of where and how the threat is presented is necessary.

Highly-enriched uranium (HEU) and separated plutonium, the materials used to create nuclear weapons, are widely acknowledged to be beyond the capabilities of terrorist groups to produce.

[1] The White House, Office of the Press Secretary, "Remarks by President Barack Obama," Prague, Czech Republic, 5 April 2009
[2] Bunn & Velikhov, Project on Managing the Atom, *Promoting Safe, Secure, and Peaceful Growth of Nuclear Energy,* October 2010

However, with enough of this material in hand, some well-organized groups could make at least a crude nuclear bomb. U.S. intelligence has concluded that "fabrication of at least a 'crude' nuclear device was well within al Qaeda's capabilities, if it could obtain fissile material."[3] These "fissile" materials exist in hundreds of buildings and bunkers in dozens of countries, including hundreds of metric tons in the United States. The security of these materials varies depending on the country that keeps them, as each country has the responsibility to secure its own materials. There is not currently a binding global security standard for the protection of nuclear weapons materials.

While HEU and plutonium can be and have been used in nuclear weapons, they can, if altered slightly, serve peaceful purposes. From this fact arises the major complication surrounding the treatment of these two resources. Weapons-grade plutonium is capable of being fabricated into mixed oxide fuel and used in nuclear power reactors to generate electricity. HEU can be blended with natural uranium to create low-enriched uranium (LEU), which is also used in reactors to generate electricity. HEU is also used in reactors in the U.S. Navy, in research reactors around the world and in the production of medical isotopes. While HEU and plutonium are considered proliferation threats, they are also considered valuable resources for many operations. From this consideration arises the ongoing debate as to the appropriate course of action for HEU and plutonium usage.

*Significance*

In order to understand the importance of the nuclear proliferation threat, it is essential to understand the catastrophic effects that even a single terrorist nuclear bomb could cause. The amount of material required for a bomb is relatively small. The atomic bomb dropped on Nagasaki included about 13 pounds of plutonium, which easily could fit inside of a soda can. With 110 pounds of HEU,

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[3] Laurence Silberman and Charles Robb, Commission on the Intelligence Capabilities of the United States Regarding Weapons of Mass Destruction, *Report to the President of the United States*, 31 March 2005

enough to fill three quarters of a gallon jug, it is possible to create an improvised nuclear device that would have similar effects to the bomb that was dropped on Hiroshima.[4] There is enough HEU and plutonium worldwide, either separated or still inside nuclear warheads, to make roughly 200,000 nuclear weapons. A fraction of one percent of these stockpiles ending up in the wrong hands could cause a global catastrophe.[5]

Since the end of the Cold War, there have been approximately twenty documented thefts or losses of HEU or plutonium, some in as large as kilogram quantities. It is likely that there have been other cases that have gone undocumented, as many of the cases of seized materials were not noticed until well after they were originally stolen.[6] However, it appears unlikely that any undocumented stolen material is currently being used in nuclear terrorism. The United States has done an exemplary job of securing its domestic stockpiles, but many of its international counterparts cannot boast the same record. For this reason, the U.S. has launched several international initiatives to keep the materials out of terrorist hands. By removing all nuclear materials from vulnerable locations, increasing effective security measures for the remaining sites, and working to eliminate the material worldwide, the danger of nuclear terrorism can be greatly reduced.

*Technical Background*

Uranium enrichment involves increasing the percentage of the isotope uranium 235 (U-235) in order to sustain a fission chain reaction in most types of nuclear reactors. Natural uranium has a U-235 content of roughly 0.7%, with the other 99.3% being the isotope Uranium 238 (U-238). The Nuclear Regulatory Commission (NRC) defines LEU as enriched uranium that has a U-235 content of less than

[4] Peter Stockton and Ingrid Drake, Bulletin of the Atomic Scientists, *From danger to dollars: What the US should do with its highly enriched uranium,* 1 November 2010
[5] Andrew Newman and Matthew Bunn, *Securing Global Nuclear Stockpiles: The First Line of Defense in Preventing Nuclear Terrorism,* Fall 2009
[6] Stuart Gottlieb, *Debating Terrorism and Counterterrorism, 2nd Edition,* 2014

20%. LEU is used in most of the world's commercial power reactors and cannot be used in nuclear weaponry because the U-238 content is too high, prohibiting the fission chain reaction. The NRC defines HEU as uranium with a U-235 content greater than 20%. Nuclear weapons typically use HEU with an 80% or greater U-235 content. Due to the threatening nature of HEU with high U-235 content, the United States and International Atomic Energy Agency (IAEA) structure nonproliferation initiatives which address this material cautiously.

| Category of Uranium | U-235 Fraction |
|---|---|
| Depleted Uranium (DU) | < 0.711% |
| Natural Uranium (NU) | 0.711% |
| Low Enriched Uranium (LEU) | 0.711% < 20% |
| Highly Enriched Uranium (HEU) | 20% - 100% |

**Table 1:** Uranium Categories

Later in this report, there will be a discussion of downblending as an alternative to reduce proliferation threats. The downblending process involves diluting HEU with materials that have very low U-235 content in order to reduce the U-235 content to LEU levels. In nearly all cases, natural uranium or depleted uranium (typically .3% or less U-235) is used. However, during the Megatons to Megawatts deal, which will be discussed at length, the U.S. specified that 1.5% U-235 content be used to blend with HEU in order to restrict levels of uranium 234 and uranium 236 in the final product.[7] Ultimately, downblending converts a relatively small amount of HEU into a larger amount of LEU, which is then used in nuclear reactors.

Mixed oxide (MOX) fuel can be fabricated from weapons-grade plutonium. This process involves taking surplus weapons-grade plutonium and mixing it with uranium oxide in order to form MOX fuel for reactor fuel assemblies. This MOX fuel is used in nuclear reactors around the world in order to generate

[7] World Nuclear Association, *Military Warheads as a Source of Nuclear Fuel,* March 2014

electricity. The United States is currently building a MOX fuel fabrication facility in an effort to dispose of 34 metric tons of weapons-grade plutonium by converting it into fuel for use in civil reactors. However, the project has proven to be extremely costly and the president has suggested postponing the project in his fiscal year 2015 proposal.

*Historical Background*

The development of both HEU and weapons-grade plutonium can be traced back to the Manhattan Project, an effort launched during World War II that developed the first atomic weapons. Following the development of HEU technology for use in atomic weapons, its range of use was expanded to naval propulsion units and research reactors. From the 1960's to the mid-1980's, the United States supplied HEU for U.S.-origin research reactors both domestically and abroad. During the same period, the former Soviet Union was also supplying HEU abroad for the same purposes. Thus, there was a widespread prevalence of HEU even though only a few countries possessed the technology to produce it themselves.[8] There have been major efforts to reclaim all U.S. origin HEU, but "putting the toothpaste back into the tube" has proven more difficult than squeezing it out.

In 1978, the Department of Energy (DOE) initiated the Reduced Enrichment for Research and Test Reactors (RERTR) Program. It was designed to develop the technical resources to convert the reactors both within the U.S. and abroad from the use of HEU to the use of LEU through the development of new LEU fuels.[9] To date, all but five domestic HEU-fueled research reactors have been converted or shut down. In order to continue operation, the remaining reactors require new fuel whose development is underway. There has, however, been considerable reluctance to convert to LEU

[8] International Atomic Energy Agency, *Management of high enriched uranium for peaceful purposes: Status and trends,* June 2005
[9] National Nuclear Security Administration, *Reduced Enrichment for Research and Test Reactors,* 22 September 2013

based technology as there are yet operations that can only be carried out on the remaining reactors via use of HEU.[10]

The United States has used this large-scale conversion as a precedent to persuade many countries to convert or remove their HEU reactors. The U.S. also offers new fuel, new facilities and technical upgrades to existing facilities as incentives to convert.[11] Since the RERTR began, 62 HEU-fueled research reactors have been converted to use LEU fuel, and 17 reactors have been shut down in 36 countries. Ten countries have moved more than 400 kilograms of HEU from civilian sites to the U.S. or Russia for storage since 2010.[12]

Between 1945 and 1992, the United States produced 1,045 metric tons of HEU.[13] In 1992, the U.S. ceased production of HEU and has depleted roughly half of its stockpile through downblending, use in naval propulsion units and use in research reactors. While the exact amount is classified, there are approximately 500 to 600 metric tons of HEU currently being stored in the U.S. Additionally, there are roughly 800 more metric tons of HEU throughout the world, with approximately 650 metric tons owned by Russia. As of 2009, the United States stated indicated that it possessed 95.4 metric tons of weapons-grade plutonium, about twenty percent of the approximate global inventory of 495 metric tons.[14]

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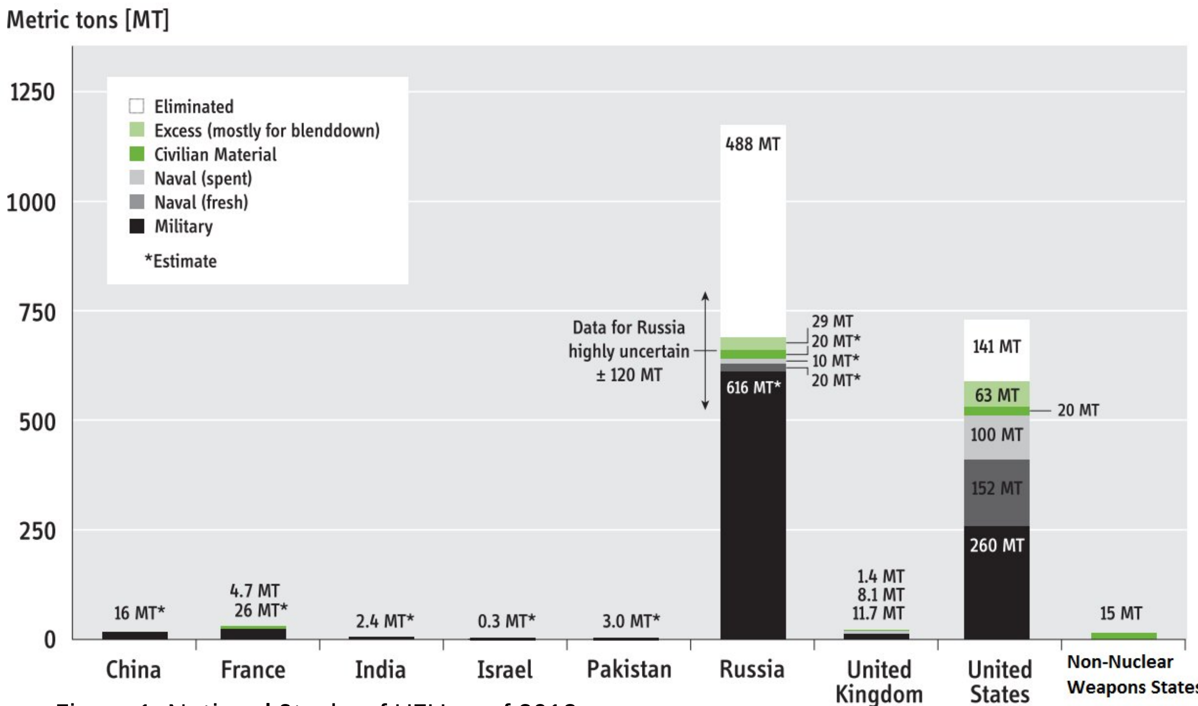
[10] Nuclear Threat Institute, *Civilian HEU: United States,* January 2014
[11] Ibid
[12] Hinderstein, Newman, and Reistad, *From HEU Minimization to elimination: Time to change the vocabulary*, 2012
[13] *Highly Enriched uranium: Striking A Balance* p. 3, January 2001
[14] International Panel of Fissile Materials, *Global Fissile Report,* 2013



[15]

Figure 1: National Stocks of HEU as of 2012

In 1993, the United States and the Russian Federation agreed to a program colloquially known as "Megatons to Megawatts". Officially known as the United States-Russia Highly-Enriched Uranium Purchase Agreement, the terms of this agreement stated that over a twenty year period, the Russian Federation would downblend 500 metric tons of its HEU reserves into LEU in Russian nuclear facilities. Then, the newly privatized United States Enrichment Corporation (USEC), appointed by the DOE, purchased and sold the LEU in U.S. markets. This was a bilateral agreement to reduce the potential threat that HEU reserves posed in the Russian Federation. In 1997, the USEC Privatization Act was signed into law, releasing the corporation of its obligation to pay for the 1.5% enriched blendstock and stipulating that USEC would transfer an equivalent amount of natural uranium to Russian ownership on

[15] Ibid

U.S. territory.[16] The program concluded in December of 2013 and was considered a success by both parties.

The Russian Federation earned roughly $17 billion dollars from the program, and USEC sold the downblended LEU to the nuclear industry to generate electricity. The U.S. government only had to supply around $300 million dollars of the entire sum, and this was due to an emergency purchase in the early stages of the agreement to keep the deal alive. The rest of sum came from the revenue from the sale of the electricity generated by LEU reactors. The LEU purchased from this program was 50% of the total LEU that the United States produced during this period, and the electricity generated from the LEU fueled reactors supplied 10% of the entire electrical consumption of the U.S. Following this agreement, the United States expressed an interest in continuing the program, but the Russian Federation declined the offer.

*Policy Aspects*

The principal political elements of the nonproliferation effort are contained in the Nuclear Non-Proliferation Treaty (NPT). The NPT is an international treaty with the objectives of preventing the spread of nuclear weapons and promoting peaceful uses of nuclear power. It recognizes five nations as "nuclear weapons states" and specifies that non-nuclear weapons states must agree to never acquire nuclear weaponry. In exchange, the nuclear weapons states agree to share the benefits of peaceful nuclear technology and strive toward global nuclear disarmament. Four United Nations (UN) member states never signed the treaty: India, Israel, Pakistan and South Sudan; North Korea officially withdrew from the treaty in 2003. Of these five nations, all but South Sudan are known or believed to possess nuclear weapons.[17] The NPT is a significant international treaty that has been an essential part of

[16] Russia Direct, *Megatons to Megawatts Program*, March 2014
[17] United Nations, *The Treaty on the Non-Proliferation of Nuclear Weapons,* May 2010

nonproliferation over the past forty years, but there are basic deficiencies in the treaty that will be discussed at greater length.

Under the NPT, the IAEA has an international safeguards system in place which is critical to preventing the spread of nuclear weapons and discouraging civil uses of weapons-grade materials. This system is essential in the monitoring and accountability of nations with nuclear programs in place. These safeguards strive to build confidence in nuclear security measures and serve as an early warning mechanism for any nation which might endanger international peace. The system would set in motion responses from the international community should a threat occur. As nuclear energy grows and spreads, there will be increasing demands on the IAEA to maintain these safeguards. Thus, increased funding from the United States and other member nations will be important to the sustainability of these measures.[18]

Arguably the second most important piece of nonproliferation policy is UN Security Council Resolution 1540, which requires UN member states to "have and enforce appropriate and effective measures against the proliferation of nuclear...weapons." This resolution presents the U.S. and other nuclear weapons states with the obligation to provide assistance upon request to those states trying to implement said measures. While "appropriate and effective measures" are not specifically defined, each member state is subject to inspection and monitoring by the IAEA to ensure the adequacy of its provisions. Best global security practices are evaluated, noted and recommended through these inspections. Since its implementation, the United States has not only put measures in place to implement all of its domestic obligations under the resolution, it has also encouraged other member

[18] International Atomic Energy Agency, *Safeguards Mission,* 27 November 2013

states to implement similar measures and has contributed $4.5 million to further the implementation of Resolution 1540.[19]

The United States has signed but has yet to ratify the Comprehensive Test Ban Treaty (CTBT), which would, if fully ratified, prohibit nuclear test explosions and serve to reduce the amount of weapons-grade nuclear material worldwide. The U.S. is one of eight remaining nations whose ratification is required in order to put the CTBT into effect. One of these nations, Iran, has said that it would sign and ratify the treaty if the United States proved that it was significantly reducing its weapons-grade materials. Without significant evidence produced by the United States, Iran remains apart from the treaty.[20] The CTBT was adopted by the UN in 1996, and after nearly twenty years of inactivity, it is a hoped-for but unlikely provision to the nuclear nonproliferation effort.[21]

The U.S. has implemented numerous regulations, which are domestic rules put in place by a country; treaties, which are international agreements; and initiatives, which could be either domestic or international, designed to prevent proliferation. While an all-encompassing discussion is beyond the scope of this paper, the following efforts have been made by the United States to secure nuclear warheads and materials:

- The Cooperative Threat Reduction Program, more widely known as the Nunn-Lugar Act, funds the Department of Defense (DOD) to dismantle and control the former Soviet Union's weapons of mass destruction. It has since expanded its mission to Southern Asia and parts of Africa. The U.S. government has allocated roughly $500 million per fiscal year since 2012 for this program.[22]

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[19] U.S. Department of State, *UN Security Council Resolution 1540*¸February 2014
[20] Masud, *Rebuffed by U.S., India, Pakistan Storm Nuclear Club*, 1 June 1998
[21] United Nations, *Comprehensive Test Ban Treaty,* 2014
[22] Justin Bresolin, *Fact Sheet: The Nunn-Lugar Cooperative Threat Reduction Program*, June 2014

- The Material Protection, Control and Accounting Program (MPC&A) was established in 1992 through the National Nuclear Security Administration (NNSA), a part of the DOE. Its goal is to assist Russia and other states of the former Soviet Union to consolidate HEU and plutonium into fewer buildings and convert this material to non-weapons-usable forms. It has also been used in to improve security and accountability in China and Pakistan. The MPC&A has received over $4 billion in funding since its inception and has requested $305 million for fiscal year 2015.[23]
- The NNSA launched the Global Threat Reduction Initiative (GTRI) in 2004 to address the threat posed by HEU-fueled research reactors worldwide. The program funds conversion of HEU reactors to LEU, removal of HEU from reactors that no longer require it, and improving security for research reactors and radioactive materials. The GTRI has received over $2 billion since its inception and has requested $333 million for fiscal year 2015.[24] Through these programs and others, the United States has taken large steps in securing and removing its own weapons materials and has been heavily involved in ensuring that other nations do the same.

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|---|---|
| Conversion to LEU: | Converted 49 HEU Reactors in 25 countries. |
| Removal of HEU: | Removed all weapons-usable HEU from 16 countries. |
| Security Upgrades: | Physical protection upgrades at 1,700 buildings. |

Table 2: Accomplishments of the GTRI as of May 2014

*Key Conflicts*

The aforementioned programs and many other international efforts have greatly reduced the threat posed by the world's highest-risk nuclear stockpiles and have demonstrated what can be done to

[23] Department of Energy, *FY 2015 Statistical Table by Organization*, 2014
[24] Ibid

continue to address these threats. However, there are several hurdles impeding further progress. These obstacles stem from the fact that half a dozen countries possess at least 20 tons of HEU and/or plutonium spread out in hundreds of buildings and the fact that a tiny fraction of this material could cause large-scale damage[25]. Fully securing the material has proven difficult due to varying international security standards and priorities and because there is no binding set of global security standards.

As mentioned earlier, Resolution 1540 requires that "appropriate and effective" measures be taken to secure nuclear material. The IAEA monitors various security standards worldwide, which allows best security practices to be highlighted and encouraged. However, there are no specific penalties for not adhering to these measures. Without mandatory standards and penalties for non-compliance, the resolution lacks provisions to enforce and the ability to enforce them. If a member state were unwilling to adopt more stringent security measures, there would be little the Security Council could do outside of imposing international sanctions, which can be difficult to agree upon and more difficult to enforce. According to information provided by the Center for Nonproliferation Studies (CNS), the UN could adopt penalties and stricter standards, but an effort has been made to achieve consensus on such topics, and no such consensus has yet been reached.[26] As of now, the problems of enforcing international sanctions or imposing other penalties have not been experienced in implementing Resolution 1540, but the concerns are seen to be viable.

The same cannot be said for the NPT, which is acknowledged to have basic deficiencies.[27] One of the largest loopholes in the NPT is that the treaty allows members to withdraw on three months' notice. This has already been seen when North Korea gave notice of its withdrawal in January of 2003 and tested a nuclear weapon shortly thereafter. Following its withdrawal, North Korea announced in

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[25] International Panel on Fissile Materials, *Fissile Material Stockpiles*, 10 January 2012
[26] Excerpt from personal communication with Mr. Leonard Spector of the CNS on 2 July 2014
[27] Gilinsky and Sokolski, *Serious Rules for Nuclear Power without Proliferation*, February 2013

February 2005 that it possessed nuclear weapons.[28] There were allegations that North Korea joined the NPT, started producing plutonium using a small reactor and began an illegal enriched uranium weapons program with resources provided by other member states. Once it obtained sufficient materials and technology, it withdrew from the treaty. This is seen as a major problem in the NPT that goes hand in hand with the fact that the treaty by and large restricts IAEA inspections. Without third party inspections, there is little to no accountability, and the effects of this shortcoming have already been witnessed.

A unique provision of the NPT is that is does allow for actions to be taken when violations occur, as has been seen with Iraq and Libya, who were suspected of violations of the NPT. However, the NPT lacks an established enforcement system, meaning that each violation requires an improvised response from the more powerful nuclear weapons states.[29] In the two aforementioned cases, each country was caught with enrichment facilities and more research and development facilities than they had declared. Iraq and Libya agreed to extensive inspections and have since been cooperative under the NPT.

Another significant issue when it comes to proliferation threats is how the U.S. and the rest of the member states diplomatically engage the countries that have not joined the NPT. According to information provided by the CNS, India, Israel and Pakistan are not being pressured to abandon production of weapons-grade material and join the NPT. The United States maintains a diplomatic relationship with these countries. The U.S. respects the security needs of Israel and Pakistan and provides them with some foreign aid, but it does not assist with their purported weapons programs

[28] Kahn, *North Korea Says It Will Abandon Nuclear Efforts,* 19 September 2005
[29] Gilinsky and Sokolski, *Serious Rules for Nuclear Power without Proliferation*, February 2013

financially or otherwise, and condemns countries that do.[30] As of now, this course of action has largely proven to be appropriate, but this could quickly and easily change, prompting an improvised response.

| | FY 2013 | FY 2014 | FY 2015 Projected |
|---|---|---|---|
| Nunn-Lugar | 519.1 | 500.5 | 365.1 |
| MPC&A | 573.4 | 369.6 | 305.5 |
| GTRI | 501 | 424.5 | 333.5 |
| Total | 1,593.5 | 1,294.6 | 1,004.1 [31] |

Table 3: Cost of Programs (In Millions of Dollars)

There are significant cost issues when it comes to managing proliferation threats. The United States allocates over $1 billion per year just in the previously-discussed programs alone. These programs deal largely with security, which is essential to proliferation protection now, but future action should involve reduction and removal of these materials. There are several ways to reduce the global stockpiles of HEU and plutonium, one of which is to convert them to fuel for use in power reactors, as noted earlier. In 2000, the United States entered into a bilateral agreement with Russia to convert 34 metric tons of weapons-grade plutonium into fuel for use in civil reactors. The cost ballooned from an initial estimated total cost of $3.1 billion to $18 billion for the plant and its operations.[32] As a result of the nearly 600% increase in estimated cost, the president's proposed fiscal year 2015 budget declared that it is placing the MOX Fuel Fabrication Facility into "cold-standby." The administration remains committed to the agreement while the NNSA evaluates "alternative plutonium disposition technologies to MOX that will achieve a safe and secure solution more cost effectively."[33] While the large costs of

[30] Excerpt from personal communication with Mr. Leonard Spector of the CNS on 2 July 2014
[31] Department of Energy, *FY 2014 Statistical Table by Organization*, 2013 & Department of Energy, *FY 2015 Statistical Table by Organization*, 2014
[32] Clements, Lyman, and von Hippel, *The Future of Plutonium Disposition*, August 2013
[33] Office of Management and Budget, *Fiscal Year 2015 Budget of the U.S. Government*, 2014

proliferation protection programs can be justified because of their effectiveness, it is difficult to recommend spending more money on proliferation programs when the total cost is already in the tens of billions of dollars. However, it the alternatives are even more expensive or less secure, this may still end up as the preferred course of action.

There is an argument that restricting the use of HEU unfairly disadvantages developing nations in their efforts to grow their civil nuclear infrastructures.[34] According to information provided by the Nuclear Threat Initiative (NTI), there is a level of prestige associated with using HEU research reactors, which are considered by some to be more cutting-edge than their low enriched counterparts.[35] Thus, the concern is that technical progress in the nuclear industries of developing countries would be constrained if they gave up their HEU-fueled facilities. Since most of the countries that have HEU-fueled facilities do not have the capability of producing HEU, the only way for them to get it is to buy it from countries that do make it. To this extent, the U.S. has been successful in combating the problem by halting its production of HEU. However since the U.S. is not the only country that produces HEU, this issue remains a political hurdle moving forward.

*Actions and Alternatives*

A 2010 report commissioned by the NTI defined three areas that ran the highest risk of nuclear proliferation. These areas were based on the quantity and quality of nuclear stockpiles, the security levels in place, and the threats that these security measures must protect against. From these qualifications, the report identified one of the three highest risk areas as HEU fueled research reactors, both domestic and abroad, which often have only minimal security measures in place.[36] The other two

[34] Hinderstein, Newman, and Reistad, *From HEU Minimization to elimination: Time to change the vocabulary*, 2012
[35] Excerpt from personal communication with Dr. Andrew Newman and Ms. Kelsey Hartigan of the NTI on 18 June 2014
[36] Matthew Bunn, *Securing the Bomb,* 2010

were noted as Russia and Pakistan. The specific needs of Russia and Pakistan are beyond the scope of this paper, but several of the previously-discussed programs address some of the issues presented by these two countries.

The first alternative in the way of handling HEU-fueled research reactors is to continue to convert them to LEU. This involves the United States and other nations continuing to adequately fund research and development of LEU alternatives both independently and through contributions to the IAEA. It also involves diplomatic engagement and financially or otherwise persuading nations with remaining research reactors to convert them.

A second alternative is to delay or forgo an initiative to convert research reactors to LEU and dedicate funding to security. This alternative is more realistic, as it is subject to less variability between nations and can continue to be accomplished through the programs already put in place by the United States. Economically speaking, this effort would continue to be funded through the programs already mentioned and would be easier on the U.S. budget. However, for practical purposes, this does relatively little to eliminate the threat of nuclear proliferation posed by research reactors, but rather protects against it. Ideally, the IAEA would develop a global security standard, which could be established through diplomatic engagement by nuclear weapons states. Once all the research reactors have been secured to this standard, conversion would then be implemented, making this alternative more of a step in the process.

A third alternative is to move toward the path of shutting down HEU-fueled research reactors. According to the NTI, given the appropriate funds, it would be more beneficial for proliferation purposes to shut down any remaining HEU research reactors rather than to secure and convert them. In terms of eliminating nuclear threat, this is beneficial for two reasons. Economically, there would not be a need for continued security or enhanced security standards on these reactors, nor would it be necessary to develop alternative LEU technologies to replace them. The second reason is that this weapons-grade material would be returned to their country of origin, likely the United States or Russia, which have far better security than their current locations.[37] Since the United States and Russia have programs already in place to downblend and eliminate their existing HEU surplus, this would also take a step toward elimination of proliferation threats.

However, there are many difficulties in implementing an alternative such as this. Strictly speaking, many of the countries who would agree to abide by these changes have already done so, and the rest have presented resistance.[38] Implementation of this alternative requires international consent, which may be increasingly difficult to obtain. In addition, the scientific developments brought about by HEU research reactors would cease to exist. This alternative also would contravene at least a part of the intent of the NPT, which promises the benefits of peaceful uses of nuclear weapons technologies to non-nuclear weapons states if they promise to not develop nuclear weapons. Despite the benefits of this alternative, the feasibility and drawbacks appear far too great to implement this strategy with any degree of success.

In addition to efforts involving reactors, the U.S. can reduce the proliferation threat by getting rid of its surplus weapons-grade uranium. As opposed to MOX fuel conversion, an economically feasible proliferation reduction strategy is domestic downblending of HEU to LEU. Not only does downblending greatly reduce the proliferation threat, it also has the potential to create revenue for the U.S. government and/or private industry as well as to supply enormous amounts of LEU for use in nuclear

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[37] Excerpt from personal communication with Dr. Andrew Newman and Ms. Kelsey Hartigan of the NTI on 18 June 2014

[38] Matthew Bunn, *Securing the Bomb,* 2010

reactors to generate electricity. Therefore, another alternative is to downblend the United States' surplus HEU reserves.

The reduction of the proliferation threat is easily justifiable. The less HEU that exists, the less opportunity for a terrorist group to acquire the amount needed to build a nuclear bomb. Additionally, non-nuclear weapons states are not likely to agree to additional constraints unless they see nuclear weapons states -- particularly the United States, which holds the largest nuclear weapons stockpiles -- upholding their end of the nonproliferation bargain.[39] If the U.S. can reduce its domestic stockpiles, there will be a larger incentive for other nations to do the same.

Financially, using the economics of the Megatons to Megawatts deal, it is possible to provide a rough estimate for how much the U.S. government and/or private industry stands to gain from downblending. As stated earlier, Russia earned roughly 17 billion dollars from downblending its 500 metric tons of HEU to create 150,000 metric tons of LEU. If the U.S. were to downblend 500 metric tons of its HEU, it stands to reason that it would earn roughly the same amount. However, if the U.S. were to adhere to the same standards to which it held Russia, it would have to purchase blendstock enriched to 1.5% U-235 content from Russia, which the Russians supplied themselves during Megatons to Megawatts. The U.S. would need to pay between 10 and 15 million dollars for blendstock per one ton of HEU, totaling about 7.5 billion dollars for 500 metric tons of HEU.[40] Subtracting this cost from the $17 billion leaves approximately 10 billion dollars. The U.S. has the capabilities to downblend 20 metric tons of HEU per year, as it did in 2004, so there would be little to no cost to create or upgrade downblending facilities.[41] Of course, there would be variability on the specifics of the amount of HEU to be

[39] Bunn & Velikhov, Project on Managing the Atom, *Promoting Safe, Secure, and Peaceful Growth of Nuclear Energy,* October 2010
[40] Russia Direct, *Megatons to Megawatts Program,* March 2014
[41] Peter Stockton and Ingrid Drake, Bulletin of the Atomic Scientists, *From danger to dollars: What the US should do with its highly enriched uranium,* 1 November 2010

downblended and the price of the blendstock, as well as if the U.S. government were to fund the start up costs or designate a non-government company, such as USEC to fund it as it did in Megatons to Megawatts. The profits of downblending would go either to the company or the government depending on which agency was tasked to fund the initial cost. This financial analysis provides a rough estimate of 10 billion dollars that the U.S. could earn if it were to downblend.

Note that while 500 metric tons was selected as a figure which correlated to the Megatons to Megawatts program, the U.S. Navy currently has reserved 100 to 160 metric tons for future use. The Navy uses 2 to 3.5 metric tons annually, which means this is enough fuel supply for the next 28-80 years.[42] Assuming no significant technological advances have been made, the Navy will require more fuel at this time.

As noted, 500 metric tons of HEU when downblended would yield about 150,000 metric tons of LEU, which would be a substantial addition to the LEU market.[43] From this fact arises some level of concern about flooding the LEU market and damaging the economic viability of the uranium mining and enrichment industries. This could be alleviated, to some extent, through storage of LEU and a publicized accounting of the date and amount of scheduled releases of LEU into the marketplace. With specific detailing of the LEU that will be released, the uranium industry and other parties can adjust accordingly. The storage of LEU would require significantly less security than the storage of HEU due to its lack of use in nuclear weapons.

The other alternative is to forgo downblending and maintain appropriate security of HEU. The opposition to the downblending alternative contends that U.S. security is adequate, and there is no

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[42] Ibid
[43] Russia Direct, *Megatons to Megawatts Program,* March 2014

need to exert additional energy to downblend HEU.[44] There is also the difficulty of changing the status-quo. Currently, the DOE is downblending 2-3 metric tons of HEU per year, for financial reasons.[45] While downblending can be seen to be financially beneficial in the long term as well as a step in the reduction of the proliferation threat, there are large hurdles involved in convincing the public to agree that it should be done and providing the necessary start-up costs to get the ball rolling.

*Recommendations*

From the information gathered from articles and databases as well as personal interviews with experts in the field of nuclear proliferation, the author has put together a set of recommendations which he sees to comprise an effective strategy to reduce the proliferation threat.

1. The United States DOE should work with the IAEA to establish and implement a set of enforceable global security standards for HEU research reactors. This should be done in the next four years, which the author feels is a feasible timeline. Through programs such as the MPC&A and abiding by the precedents established in Resolution 1540, the U.S. should work to establish domestic security standards similar in nature to the most effective current reactor security. The U.S. should also diplomatically engage with world leaders to persuade them to adhere to these standards. With global research reactor security in place, there will be no easily identifiable weak links to target, and best security practices will continue to be enforced.

2. The U.S. NRC should promote accountability for research reactor security in order to keep security standards up to date, presuming HEU continues to be used as research reactor fuel. Once security standards have been established, maintaining them should be less challenging. However, accountability

[44] International Security Advisory Board, *Report on Proliferation Implications of the Global Expansion of Civil Nuclear Power,* 7 April 2008
[45] Peter Stockton and Ingrid Drake, Bulletin of the Atomic Scientists, *From danger to dollars: What the US should do with its highly enriched uranium,* 1 November 2010

to the IAEA is essential in order to maintain standards. The U.S. should make publicly available its most current security standards and persuade other countries to do the same.

3. The U.S. DOE should continue to seek alternatives for plutonium disposal. Because MOX fuel fabrication appears to be costly in the United States, the nation should continue to evaluate economic alternatives for plutonium disposal. The country should evaluate and consider the feasibility of practices employed by Russia, which is the other part in the bilateral plutonium disposition agreement.

4. The U.S. NNSA should make available on a nation by nation basis the LEU technology that has been used domestically and can be implemented. The U.S. should try to persuade other nations to convert to LEU technologies for their research reactors.

5. The United States DOE should increase the rate at which it downblends its surplus HEU. This will serve to reduce the proliferation threat, generate income and provide material for use in LEU reactors. Since the U.S. already possesses the capability to downblend more HEU, this would not require significant costs.

6. The U.S. should exert the domestic downblending effort as a tool to effectively convince other countries to convert their HEU stocks as well. With a public initiative by the United States in place, the country should work diplomatically to persuade other nations to employ a similar practice.

7. The U.S. Department of State should continue to engage countries that have not joined, withdrawn, and/or violated the conditions of the NPT. The United States should engage in direct diplomatic efforts with India, Israel, North Korea and Pakistan, offering credible, international packages of incentives and disincentives in order to convince them that is in their best interests to give up their nuclear weapons ambitions. The U.S. should inform these nations of security standards that the United States employs as well as recommend security measures and consistent checks to maintain appropriate security levels.

8. The United States should fund the IAEA to strengthen nuclear safeguards and encourage other countries to follow suit. The U.S. should work with other nations to increase IAEA's budget and expand their voluntary contributions to the IAEA safeguard program. The U.S. should also increase its domestic research and development program to develop improved safeguard technologies.

9. The United States should work with other nations of the UN to pass a resolution legally imposing additional safeguards and sanctions on any state that violates the NPT.

10. The United States should ratify the Comprehensive Test Ban Treaty. With the ratification of the CTBT by the U.S., a new precedent would be established for the remaining seven nations to ratify as well. This will prevent any further nuclear test explosions and initiate new discussions to reduce excess HEU and plutonium stockpiles.

11. The United States DOE should pursue strategies that would provide reliable, economic supplies of fuel to nations undertaking new or additional nuclear power plants.

12. The U.S. should work with other nuclear weapons states to establish guidelines by which to judge fuel recipients' efforts to forgo enrichment and reprocessing capabilities. The U.S. should develop criteria and procedures for halting the supply of fuel and hardware to any nation found to be in violation of the NPT. The U.S. should make it clear to nations that compliance with the NPT is essential in order to maintain a good diplomatic relationship with the United States.

## Glossary

Blendstock - Material used to dilute to concentration of uranium-235.

Downblending - The reduction of uranium enrichment levels from 80-90 percent to less than 20 percent. This low enriched uranium is of little use to terrorists and is suitable for use as material in nuclear power plants.

Fissile - Material, such as Uranium 235, which readily undergoes fission.

Highly-enriched uranium - The definition for highly-enriched uranium is variable and can be categorized as any uranium with a U-235 content of 20% or higher. However, nuclear weapons rely on highly-enriched uranium with a U-235 content of 80% or higher, such that it is composed of atoms that can release enormous amounts of energy from a self-sustaining chain reaction.

Improvised nuclear device - A device that can be created using approximately 100 pounds of highly-enriched uranium to trigger a detonation of a magnitude close to that which devastated Hiroshima.

Low-enriched uranium - A safer form of uranium, from a weapons perspective, with less than 20% content of U-235. Low-enriched uranium is not capable for use in weapons, but can be used in nuclear reactors.

Metric tons - A unit of weight that is equivalent to 1,000 kilograms or 2,204.6 pounds.

Natural uranium - Uranium as found in nature with U-235 content of 0.711%.

## Acronyms Used

CNS - Center for Nonproliferation Studies

CTBT - Comprehensive Test Ban Treaty

DOD - Department of Defense

DOE - Department of Energy

GTRI - Global Threat Reduction Initiative

HEU - Highly-Enriched Uranium

IAEA - International Atomic Energy Agency

LEU - Low-Enriched Uranium

MOX - Mixed Oxide

MPC&A - Material Protection, Control and Accounting

NNSA - National Nuclear Security Administration

NPT - Non-Proliferation Treaty

NRC - Nuclear Regulatory Commission

NTI - Nuclear Threat Initiative

RERTR - Reduced Enrichment for Research and Test Reactors

UN - United Nations

USEC - United States Enrichment Corporation

# Works Cited

[1] Bresolin, Justin, and Brenna Gautam. "Fact Sheet: The Nunn-Lugar Cooperative Threat Reduction Program." Center for Arms Control and Non-Proliferation, 2014. Web.

[2] Bunn, Matthew. *Securing the Bomb*. Rep. Cambridge: Harvard U, 2010. Project on Managing the Atom, Apr. 2010. Web.

[3] "Civilian HEU: United States." *Nuclear Threat Initiative*. 24 Jan. 2014. Web.

[4] Clements, Tom, Edwin Lyman, and Frank Von Hippel. "The Future of Plutonium Disposition." Arms Control Association, July-Aug. 2013. Web.

[5] "Comprehensive Nuclear Test-Ban Treaty." *United Nations Office for Disarmament Affairs*. United Nations, 2014. Web.

[6] Gilinsky, Victor, Henry Sokolski, and George Perkovich. "Serious Rules for Nuclear Power without Proliferation." Carnegie Endowment for International Peace, 18 Mar. 2012. Web.

[7] *Global Fissile Report*. Rep. International Panel on Fissile Materials, 2013. Print.

[8] Gottlieb, Stuart. *Debating Terrorism and Counterterrorism: Conflicting Perspectives on Causes, Contexts, and Responses*. 2nd ed. Washington, D.C.: CQ, 2014. Print.

[9] Hinderstein, Corey, Andrew Newman, and Ole Reistad. "From HEU Minimization to Elimination: Time to Change the Vocabulary." *Bulletin of the Atomic Scientists* 68.4 (2012): 83-95. Web.

[10]Kahn, Joseph. "North Korea Says It Will Abandon Nuclear Efforts." *The New York Times*. 19 Sept. 2005.

[11]Laurence Silberman and Charles Robb (co-chairs), Commission on the Intelligence Capabilities of the United States Regarding Weapons of Mass Destruction, *Report to the President of the United States* (Washington, D.C.: Government Printing Office 31 March 2005)

[12]"Management of High Enriched Uranium for Peaceful Purposes: Status and Trends." *Nuclear Fuel Cycle Materials Section*. International Atomic Energy Agency, June 2005. Web.

[13]Masud, Enver. "Rebuffed by U.S., India, Pakistan Storm Nuclear Club." *Rebuffed by U.S., India, Pakistan Storm Nuclear Club*. The Wisdom Fund, 1 June 1998. Web.

[14]"Megatons to Megawatts Program." *Russia Direct Quarterly Report* 4 (2014). Web.

[15]Mian, Zia. "IPFM Releases Global Fissile Material Report 2011: Nuclear Weapon and Fissile Material Stockpiles and Production." International Panel on Fissile Materials, 10 Jan. 2012. Web.

[16]"Military Warheads as a Source of Nuclear Fuel." *World Nuclear Association*. Mar. 2014. Web. 7 July 2014.

[17]Newman, Andrew, and Kelsey Hartigan. Personal interview. 18 June 2014.

[18]Newman, Andrew, and Matthew Bunn. "Securing Global Nuclear Stockpiles: The First Line of Defense in Preventing Nuclear Terrorism." *The Fletcher Forum of World Affairs* 33.2 (2009): 109-28. 26 July 2012. Web.

[19]"Nuclear Nonproliferation Treaty." U.S. Department of State, 2014. Web.

[20]Project on Managing the Atom and Russian Research Center "Kurchatov Institute". *Promoting Safe, Secure, and Peaceful Growth of Nuclear Energy: Next Steps for Russia and the United States.* Cambridge, Mass.: Report for Belfer Center for Science and International Affairs, Harvard Kennedy School, October 2010

[21]"Reduced Enrichment for Research and Test Reactors (RERTR)." *Argonne National Laboratory*. U.S. Department of Energy, 5 Feb. 2013. Web.

[22]*Report on Proliferation Implications of the Global Expansion of Civil Nuclear Power*. *Department of State*. International Security Advisory Board, 7 Apr. 2008. Web.

[23]"Safeguards Mission." International Atomic Energy Agency, 27 Nov. 2013. Web.

[24]Spector, Leonard. Personal interview. 2 July 2014.

[25]Stockton, Peter, and Ingrid Drake. "From Danger to Dollars: What the US Should Do with Its Highly Enriched Uranium." *Bulletin of the Atomic Scientists*66.6 (2010): 43-55. Web.

[26]The White House, Office of the Press Secretary, *Remarks by President Barack Obama,* Hradcany Square, Prague, Czech Republic, 5 April 2009.

[27]"UN Security Council Resolution 1540." U.S. Department of State, May 2014. Web.

[28]United States. Department of Energy. *FY 2014 Statistical Table by Appropriation*. *FY 2014 Congressional Budget Request*. 2013. Web.

[29]United States. Department of Energy. *FY 2015 Statistical Table by Appropriation*. *FY 2015 Congressional Budget Request*. 2014. Web.

[30]United States. Department of Energy. Office of the Deputy Administrator for Defense Programs. *Highly Enriched Uranium: Striking a Balance*. Jan. 2001. Web.