Research Report

Nuclear Security Summit

Reducing the quantity of dangerous nuclear materials in the world

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Introduction

Nuclear radiation was discovered in 1896 by Henri Becquerel, which soon would revolutionize weapons and power. Becquerel discovered nuclear radiation when he was studying phosphorescence (i.e. the ability to glow in the dark). He initially hypothesized that this property was related to x-ray however soon discovered a new form of radiation. He discovered this ionizing radiation when he was experimenting on uranium, as its compounds are phosphorescent. After this discovery Marie Curie began to experiment to find the origin of the radioactivity. The names Becquerel and Curie still live on where the Curie and the Becquerel measure radioactivity; the Curie being the common unit while the Becquerel being the SI unit. Their work has had a profound affect on our knowledge of the radioactive properties of nuclear materials.

In this year's NSS, held in The Hague, following earlier summits in Washington (2010) and Seoul (2012), new agreements have been made concerning reducing the quantity of dangerous nuclear materials in the world, which terrorists could use to make nuclear weapons (i.e. highly enriched uranium). These agreements entail keeping the quantities of nuclear materials as small as possible, as the "smaller the amount of the nuclear weapons, the smaller the risk" (as specified in the Dutch government site page Outcomes of NSS 2014). Additionally, agreements have been made stating that countries that do choose to use Highly Enriched Uranium in their nuclear generators will attempt to constrain the amount of said material.

Setting the stage for the first 2010 summit held in Washington, Barack Obama stated that nuclear weapons are "the single biggest threat to [...] security." He further stated that the "central focus for this summit is getting the international community on the path in which we are locking down that nuclear material in a very specific time frame with a specific work plan." This statement still applied for the following summits in Seoul and The Hague, and certainly will apply for further summits. Hence, reducing the amount of dangerous nuclear materials like HEU is perhaps the most effective way to sustain international "security" and peace.

Definition of Key Terms

Nuclear Materials

As defined by the International Atomic Energy Agency (IAEA), it is an umbrella term for uranium, plutonium and thorium in any form. It is most commonly used for fissile materials that are capable of creating a chain reaction, which releases nuclear fission energy.

Ionizing Radiation

A harmful form of radiation for living tissue created by removing electrons, which subsequently charges neutral atoms.

Highly Enriched uranium (HEU)

A form of uranium that is enriched above 20%. Normally Uranium is found in its stable form U-238 and in its radioactive form U-235. Enriched uranium implies an increased concentration of the radioactive U-235 in the natural uranium. HEU is an important component of nuclear generators and nuclear weapons.

Low Enriched Uranium (LEU)

A form of uranium that is enriched below 20% in U-235.

Weapons Grade Uranium

A form of HEU, which is enriched to approximately 90%. Nuclear weapons can be created with HEU that hasn't been enriched to the same extent, however a larger quantity would be required.

General Overview

To reduce the quantity of dangerous nuclear materials, as explicitly stated in the "Nuclear Material" section of the 2014 NSS communiqué, HEU should be "down-blended" to low-enriched uranium (LEU) and separated plutonium should be converted to mixed oxide

(MOX) fuel. This is because HEU and separated plutonium are used in nuclear weapon creation.

Highly enriched uranium

Creation of HEU (Enrichment)

In order to obtain HEU, large amounts of uranium must be mined. Uranium mining occurs in a limited number of countries. In total, there are 18 countries mining uranium, with about a third of this activity occurring in Kazakhstan.

After obtaining raw uranium, in order to make it into HEU, this uranium must be enriched. The enrichment processes are all similar in the way that they separate the U-235 and U-238 isotopes in natural uranium and increase the concentration of the U-235 isotope above 20%. Enrichment facilities all require enormous amounts of energy, technological advancement and a technically educated labor force. According to the Institute for Energy and Environmental Research only 14 countries have uranium enrichment plants: Argentina, Brazil, China, France, Germany, India, Iran, Japan, the Netherlands, Democratic People's Republic of Korea, Pakistan, Russia, the United Kingdom, and the United States.

There are multiple methods for the enrichment of uranium: gaseous diffusion, gas centrifuge, and laser separation.

HEU stockpiles

While there are international efforts to reduce HEU stockpiles, there is still a large amount remaining. According to the International Panel on Fissile Materials (IPFM) the global supply of HEU has reduced from 2000 tons to approximately 1380 tons as of 2013. Russia and the USA combined have 98% of the world's HEU stockpiles.

Uses of HEU

HEU has civilian uses in research reactors. These reactors are small fission reactors made for "scientific research, training, and medical isotope production" by producing neutrons (Nuclear Threat Initiative). These small reactors are much less powerful than commercial reactors and also require much less uranium. Initially many reactors used LEU, however, in the late 1950s these were not able to achieve the power needed for research. Since HEU has more U-235, these reactors can create a higher neutron flux. On the other hand, technology has advanced significantly, allowing for

LEU reactors to be able to meet the demands for these neutron research reactors. A variant of these research reactors are low-power research reactors. These reactors function on even lower power and thus do not require an equally elaborate cooling system. IAEA estimates that there are 246 research reactors currently operating.

HEU has civilian uses in radioisotope production. These radioactive isotopes play a significant role in medical applications, primarily molybdenum-99. Molybdenum-99 is created with HEU targets, which are exposed to radiation in reactors, which subsequently produce the fission product. There are multiple international companies that still rely on HEU as opposed to LEU for the creation of these radioactive isotopes today including: Covidien, IRE and Nordion. However, some producers of these medical isotopes have begun to produce using LEU targets. This has occurred in smaller facilities in Argentina, Australia and Indonesia. Additionally, at a much larger scale the South African SAFARI-1 reactor has been converted to use LEU targets producing molybdenum-99. IAEA was a significant proponent of this conversion aiding them with an International Working Group.

HEU has civilian uses in space exploration. There are satellites that orbit the earth using weapon grade HEU fission reactors. HEU is used particularly due to the space, weight and economical constraints imposed by space launches. The first satellite to use this technology was launched by the United States in 1965. Additionally, these reactors were often used by the Soviet Union during the Cold War. In 2005 the US secretary of Energy (Bodman) allocated 24 tons of weapon grade HEU for space reactors. There have been several successful demonstrations of space nuclear reactors that use HEU, for example ones from NASA. This demonstrates that, while HEU has significant drawbacks when used with destructive intentions, it does also provide a viable solution for space exploration.

HEU has civilian uses in naval propulsion reactors. Russia currently is the only country which uses nuclear propulsion for its civilian boats. Russia introduced their first nuclear icebreaker ship in 1957, named Lenin. Its reactors initially used LEU, however, in order to increase the distance traveled by ships, those were made to use HEU. Its OK-900 reactors used 36-45% HEU as opposed to the predecessor’s OK-150 reactors which used 5% LEU. There is a significant amount of uranium in the ship’s reactor cores reaching 200 kg. At the moment Russia has 5 operation nuclear icebreaker ships.

HEU has civilian uses in fast reactors power generation. Initially HEU nuclear reactors were the standard however, now the majority of the 435 commercial nuclear power reactors run on LEU (some of which run on MOX). There have been multiple significant moments in terms of the conversion of reactors from HEU to LEU. For example, France shut down their HEU Superphenix reactor in 2009 to pursue the alternative MOX reactors. However, many countries still utilize HEU in their fast reactors. Fast reactors are made so that they produce more fissile material than what they use. It is imperative that the NSS encourage and stimulate alternative nuclear power reactors that do not rely on HEU. United States started the Gen IV Nuclear Energy Systems International forum while IAEA started Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO), both aiming to explore and discover more sustainable nuclear power technology.

HEU has military uses in nuclear weapon creation. There are two forms of nuclear weapons: fission weapons and fusion weapons. Nuclear fission weapons require highly enriched uranium. These weapons normally contain 85% HEU while 20% is a minimum. The first uranium bomb used on Hiroshima with devastating affects was made up of 64 kg of 80% HEU. In 2013 the United States stated that it has 204 tons of excess HEU. However, the United States has changed 141 tons of this excess HEU into LEU and will have changed all of it into LEU by 2050. Russia too is converting its excess HEU into LEU by agreeing to the "Megatons for Megawatts Program." There they agreed to convert 500 tons of HEU into LEU, which will ultimately be used for fuel for nuclear reactors.

Separated plutonium

Creation of separated plutonium

Using nuclear reprocessing technology creates separated plutonium. Initially reprocessing technology was used to obtain separated plutonium solely for weapon creation. The irradiated fuel (concentrated uranium) used in reactors can be reprocessed to obtain fissile materials like plutonium. The plutonium is created from the uranium fuel in nuclear reactors. The uranium-238 absorbs an additional neutron and becomes uranium-239. The uranium-239 then decays, becoming plutonium-239. This plutonium-239 is found in the waste product, which accumulates over time. This is because the uranium used in reactors has a life span of usually 4 years, and thus over time creates a large amount of waste product, making the reactor inefficient. Reprocessing separates the radioactive waste from the useful fissile plutonium. There are multiple methods of reprocessing however the current universal method is Plutonium and Uranium Recovery by Extraction (PUREX). PUREX has a multitude of variations including UREX, TRUEX and DIAMEX.

Uses of separated plutonium

The United States has, since the late 1970s, stopped reprocessing and treating the nuclear fission products as high security waste. They have chosen to do so as to discourage nations from reprocessing and obtaining the separated plutonium nuclear weapon material. While United States has stopped its production of separated plutonium, Israel, India, and Pakistan still continue their production. Additionally, it seems that in 2013 DPR Korea also has resumed its production of plutonium.

In 2006, the estimate for the global plutonium stockpile was 250 tons. It was estimated that of this 250 tons, France possessed 50 tons while Russia had 41 tons. In 2012, the stockpile of separated plutonium was of 495 tons. About half of the stockpile of separated plutonium was made for nuclear weapon creation, while the other half was for civilian usage. Even though some nations still continue their separated plutonium production, currently there is a global net decrease of plutonium stockpiles. This is due to nations converting their separated plutonium into MOX fuel to be used back in the reactors or disposing their separated plutonium in waste plants like the Waste Isolation Pilot Plant in New Mexico.

Separated Plutonium has military uses in nuclear weaponry creation. About 10 kg of almost pure Pu-239 is needed to make a nuclear bomb. It takes about 30 megawatt years of reactor operation to obtain 10 kg of plutonium. Alternatively, nuclear bombs can be made with Pu-240. However, these are considered not feasible and less powerful than Pu-239 nuclear weapons. Weapon-grade plutonium is considered to be Pu-239 with less than 8% Pu-240. As it is not feasible to separate Pu-240 from Pu-239, the creation of weapon grade plutonium requires advanced reprocessing technology. The shutdown Magnox reactors located in the UK were once designed for both generating electricity and separating plutonium.

Separated plutonium conversion to MOX fuel

While the optimum solution for reducing the amount of dangerous nuclear weapons would be discouraging nations from nuclear reprocessing, many nations already have large stockpiles of weapon grade separated plutonium. It is possible to convert weapon grade plutonium to MOX fuel, which is less harmful and can be used for fuel in nuclear reactors. Today MOX is prevalent in European and Japanese reactors. There are approximately 40 reactors in Europe that have the license to use MOX while more than 30 actually do so. There are 10 reactors in Japan that have the MOX license and many of them are doing so. These European and Japanese reactors use more than 30% MOX in their core however some go as far as 50% of the core.

While MOX doesn't change features of the nuclear reactors, the reactors must be slightly adapted in order to use MOX fuel as opposed to concentrated uranium. MOX fuel is increasingly being used due to the much higher uranium prices today as opposed to a decade ago. Additionally, adding more plutonium can easily alter MOX fuel's fissile concentration. Whereas, increasing uranium's fissile concentration is more difficult.

Using the separated plutonium as an oxide creates MOX fuel. To form MOX fuel, separated plutonium is added to depleted uranium, which is also a byproduct of nuclear reactors. MOX fuel is made up of 7-10% plutonium while the rest is depleted U-235. However, commercial MOX is made up of 10.8% plutonium.

Timeline of Events

Date	Description of event
April 12th, 2010	Nuclear Security Summit in Washington
March 26th, 2012	Nuclear Security Summit in Seoul
March 24th 2014	Nuclear Security Summit in The Hague

UN involvement, Relevant Resolutions, Treaties and Events

- Code of Conduct on the Safety and Security of Radioactive Sources by IAEA
- 2010 Nuclear Non-Proliferation Treaty (NPT) Review Conference
- Megatons for Megawatts Program
- Resolution 1373, 28 September 2001 **(S/RES/1373)**
- Resolution 1540, 28 April 2004 **(S/RES/1540)**

Evaluation of Previous Attempts to Resolve the Issue

The 2010 Washington Nuclear Security Summit communiqué does not specifically address reducing the quantity of dangerous nuclear materials. It does however make “considerable progress” in securing and consolidating these dangerous materials. In the communiqué it also suggests cooperation at a bilateral, regional and multilateral level in nuclear technology and thus too the advancements in converting HEU into LEU. Additionally, the communiqué takes long-run steps by suggesting and facilitating nations’ reactors being converted from HEU to LEU. The communiqué facilitated an International Working Group through IAEA, which would assist in HEU to LEU conversion of reactors.

The 2012 Seoul Nuclear Security Summit communiqué does specifically address the removal of nuclear materials (4-5). While the previous communiqué encourages nations to only convert their reactors from HEU to LEU and to minimize their use of HEU, this communiqué specifically encourages nations for timely and secure disposal of these dangerous nuclear materials (HEU and separated plutonium).

The 2014 Hague Nuclear Security Summit communiqué also specifically addresses the removal of nuclear materials (21-22). It further suggests the conversion of separated plutonium to MOX fuel and explicitly reiterates the importance of disposing of HEU and separated plutonium.

These steps have made a significant development in reducing the quantity of dangerous nuclear materials in the world. However, some nations still persist in their plutonium production as stated in this report. Additionally, while fissile nuclear material stockpiles are being disposed of, many nuclear facilities are vulnerable to theft. This is shown by the many break-ins into nuclear facilities through US, France and UK. It is imperative that all nations impose the guidelines of the IAEA and the NSS communiqués, facilitate others in doing so and run long-term researches for alternative disposal methods of enriched uranium and separated plutonium.

Possible Solutions

Ultimately however, it seems as though it is crucial that a treaty is formed banning the production of weapon grade nuclear materials (including HEU and nuclear reprocessing in order to obtain Plutonium). The treaty should encompass: monitoring nuclear stockpiles and setting achievable milestones for their disposal; transparency between nations regarding fissile nuclear materials; bookkeeping in accordance to IAEA; the prohibition of the production of fissile nuclear materials. Such a treaty will be extremely difficult to implement considering that some nations still produce plutonium and use HEU reactors. Such a treaty would also cause much dispute and be extremely difficult to impose on a global scale. However, its benefits are perhaps unprecedented. As 1991 US senator Sam Nunn states “it is the duty of governments to reduce the risks that pose a threat to humanity. [...] Citizens must demand it, and leaders must answer the call. The day after a nuclear catastrophe, citizens and leaders alike would be asking what we should have done to prevent it. I continue to ask the question: Why aren’t we doing it now?” To reduce the risk entirely, weapon grade HEU and plutonium should be banned from production.

While the aforementioned is a solution in the long run, in the short run, economical and political investments as well as time should be spent on reducing the amount of nuclear weapons. With break-ins into French, American and British nuclear facilities, it is imperative that more emphasis is placed upon the security and the reduction of nuclear materials. Additionally, the reduction of nuclear materials should become universal. It is reported that Belarus has nuclear weapon grade materials and yet is not part of the summit. While the summit is based upon being in consensus and thus involves a limited number of countries, attempts also need to be made to widen its reach to those who do not participate in the summit. Additionally, the 2014 NSS national report on the Republic of South Africa did not refer to their HEU stockpiles. Steps need to be taken to further reduce plutonium and HEU stockpiles located outside of US and Russia.

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