IPFM
INTERNATIONAL PANEL
ON FISSILE MATERIALS

# Global Fissile Material Report 2013

## Increasing Transparency of Nuclear Warhead and Fissile Material Stocks as a Step toward Disarmament

Seventh annual report of the International Panel on Fissile Materials

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**On the cover:** the map shows existing and planned uranium enrichment and plutonium separation (reprocessing) facilities. See Pages 24–25 of this report for more details.

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# About the IPFM

The International Panel on Fissile Materials (IPFM) was founded in January 2006. It is an independent group of arms-control and nonproliferation experts from eighteen countries, including both nuclear weapon and non-nuclear weapon states.

The mission of the IPFM is to analyze the technical basis for practical and achievable policy initiatives to secure, consolidate, and reduce stockpiles of highly enriched uranium and plutonium. These fissile materials are the key ingredients in nuclear weapons, and their control is critical to nuclear disarmament, halting the proliferation of nuclear weapons, and ensuring that terrorists do not acquire nuclear weapons.

Both military and civilian stocks of fissile materials have to be addressed. The nuclear weapon states still have enough fissile materials in their weapon and naval fuel stockpiles for tens of thousands of nuclear weapons. On the civilian side, enough plutonium has been separated to make a similarly large number of weapons. Highly enriched uranium is used in civilian reactor fuel in more than one hundred locations. The total amount used for this purpose is sufficient to make hundreds of Hiroshima-type bombs, a design potentially within the capabilities of terrorist groups.

The Panel is co-chaired by Professor R. Rajaraman of Jawaharlal Nehru University, New Delhi and Professor Frank von Hippel of Princeton University. Its 29 members include nuclear experts from Brazil, Canada, China, France, Germany, India, Iran, Japan, South Korea, Mexico, the Netherlands, Norway, Pakistan, Russia, South Africa, Sweden, the United Kingdom, and the United States.

IPFM research and reports are shared with international organizations, national governments and nongovernmental groups. The reports are available on the IPFM website www.fissilematerials.org and through the IPFM blog, www.fissilematerials.org/blog. Princeton University's Program on Science and Global Security provides administrative and research support for the IPFM.

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# Overview

## Increasing Transparency of Nuclear Warhead and Fissile Material Stocks

*Global Fissile Material Report 2013: Increasing Transparency* is the seventh *Global Fissile Material Report* by the International Panel on Fissile Materials. It begins with an overview of current nuclear weapon stocks and of national holdings of fissile materials and then lays out a set of options for a series of increasingly detailed public declarations by nuclear weapon states of their nuclear warhead inventories, and of their production and disposition of highly enriched uranium and separated plutonium, the fissile materials that are essential in nuclear weapons. It also suggests new cooperative projects that could assist in the eventual verification of such declarations.

The declarations proposed in this report could fulfill some of the nuclear weapon state obligations under the "Action Plan on Nuclear Disarmament" agreed at the 2010 Nuclear Non-Proliferation Treaty (NPT) Review Conference and would provide essential background information required for the negotiation and verification of deep reductions in nuclear arsenals and for the eventual elimination of nuclear weapons.

In 2013, the global stockpile of nuclear weapons was estimated at over 17,000 weapons, with the United States and Russia together holding over 16,000 of these weapons and the other seven nuclear weapon states holding a combined total of about 1000 weapons.

The global stockpile of highly enriched uranium (HEU) as of the end of 2012 is estimated to be about 1380 ± 125 tons. This is sufficient for more than 55,000 simple, first-generation implosion fission weapons. About 98% of this material is held by the nuclear weapon states, mostly by Russia and the United States. The large uncertainty in the estimate is due to Russia not declaring how much HEU it produced before stopping production in the late 1980s, whereas the United States has declared its HEU holdings as of 1996 and 2004. The uncertainty in the size of the Russian HEU stockpile is larger than the combined estimated HEU stocks of all other states except for the United States.

The global HEU stockpile has been shrinking. Over the past two decades, about 630 tons of HEU has been blended down, mostly by Russia, which has eliminated a total of 488 tons as of the end of 2012. This includes 473 tons of excess weapon-grade material. The United States, which has eliminated about 141 tons of mostly non-weapon-grade HEU, has chosen to set aside 152 tons of excess weapons HEU for a naval fuel reserve. This includes 24 tons of HEU that was added to the naval stockpile in 2012, but previously had been declared excess for military purposes and earmarked for blend-down.

The United States, United Kingdom, Russia, France and China have all stopped producing HEU for weapons as well as any other purpose, in some cases decades ago. The first four of these states have made official declarations to this effect, China has done so informally. In 2012, Russia announced that it was resuming limited production of HEU for naval and fast reactor fuel. India is also producing HEU for naval fuel. Pakistan is producing HEU for weapons. It is possible that North Korea also may be producing HEU for weapons.

The global stockpile of separated plutonium in 2012 was about 495 ± 10 tons. Almost half of this stockpile was produced for weapons, while most of the rest has been produced in civilian programs in nuclear weapon states. As a result, about 98% of all separated plutonium is in the nuclear weapon states. Most of the uncertainty is due to a lack of official information about Russia's plutonium production history.

In 2012 the United States provided an update of its history of production and use of weapons plutonium and on its plutonium stockpile as of September 2009. Its earlier declaration was in 1996. The United Kingdom also has declared the size of its weapons plutonium stockpile, but only once, in 2000. The other nuclear weapon states have made public no information on their current holdings or production of weapons plutonium, other than announcing an end to production for weapon purposes. Again, China has indicated this only informally.

Israel, India, and Pakistan continue to produce plutonium for weapons. In September 2013, North Korea appears to have resumed production in its previously disabled reactor at Yongbyon. Nonetheless, there has been a net decrease in the global plutonium stockpile available for weapons in recent years as the United States has reported sending 4.4 tons of plutonium declared excess for national security needs for disposal as waste in the Waste Isolation Pilot Plant in New Mexico. This disposal has not been verified independently by international inspectors, however.

The global civilian stockpile now exceeds the military stockpile. There are civilian plutonium separation (reprocessing) programs in the United Kingdom, Russia, Japan, India, France, and China. In July 2012, the United Kingdom announced plans to close by 2018 its THORP reprocessing plant, at Sellafield. This would end reprocessing in the United Kingdom. The future of Japan's reprocessing program is unclear in the wake of the March 2011 disaster at the Fukushima nuclear plant.

### Increasing Transparency

The focus of this report is increasing transparency of nuclear warhead and fissile material stockpiles. Under the terms of the 2010 "Action Plan on Nuclear Disarmament," the NPT nuclear weapon states agreed to cooperate on steps to increase transparency and develop verification capabilities related to nuclear disarmament and in particular to report information that can further openness and verification. The nuclear weapon states are expected to report to the NPT Preparatory Committee in 2014 on progress towards meeting these obligations.

Chapter 2 of *Global Fissile Material Report 2013* lays out proposals for steps towards greater transparency that could be adopted by the NPT weapon states as part of this process. These proposals were presented by IPFM in Vienna in May 2012 and in April 2013 in Geneva at the meetings of the Preparatory Committee (PrepCom) for the 2015 NPT Review Conference. These are summarized briefly below.

In advance of the 2015 NPT Review Conference, the nuclear weapon states could make baseline declarations of the total numbers of nuclear warheads in their possession as of a specific recent date with a commitment to subsequent annual updates.

To make their declarations comparable and consistent over time, the weapon states could develop shared terminology to describe nuclear warheads and warhead components, and their deployment, storage, and stages of dismantlement. One option to provide a basic level of transparency of their strategic nuclear arsenals would be for the United Kingdom, France, and China (and the non-NPT nuclear weapon states) to adopt the reporting structure agreed by Russia and the United States in their 2011 New START treaty for strategic nuclear forces.

Since fissile materials are the key ingredients of nuclear weapons, transparency measures could usefully include declarations about fissile material stocks, production, and stockpile histories in nuclear weapon states. As part of their baseline declarations, by 2015, NPT nuclear weapon states could make public:

- Total national holdings of plutonium and of HEU as of a specific recent date;

- Amounts of HEU and plutonium in other countries and any foreign-owned material in country; and

- The portions of their HEU and plutonium stockpiles available for IAEA safeguards.

The 2010 NPT Review Conference Final Document encourages the nuclear weapon states "to declare, as appropriate, to the International Atomic Energy Agency (IAEA) all fissile material designated by each of them as not required for military purposes and to place such material as soon as practicable under IAEA or other relevant international verification and arrangements for the disposition of such material for peaceful purposes." To this end, the NPT weapon states could declare and place under IAEA safeguards:

- All plutonium and HEU in civilian use;

- All plutonium and HEU recovered from excess weapons or its nuclear-weapons complex and declared excess for weapon purposes; and

- All plutonium and HEU going to waste disposal sites.

Given the goal of further reductions and eventual elimination of nuclear weapons, the NPT weapon states should agree to begin to prepare information about their warhead and fissile material stockpiles for later disclosure in the context of deep-cuts agreements.

At the 2015 NPT Review Conference, the weapon states could commit to greater openness about their nuclear forces and lay the basis for future exchanges of information similar to those undertaken biannually by the United States and Russia on:

- The locations of deployed delivery vehicles and the number of deployed warheads at each operational base;

- The assignment of a unique identification number to each missile, aircraft, and missile launcher, whether deployed or not.

The weapon states could also agree to prepare national records that would allow them to declare:

- Total nuclear-warhead stockpiles by year and numbers of warheads built, retired, and dismantled each year; and

- Plans for future warhead production, life-extension, deployment, and disassembly for the next five years.

Along with preparing warhead and delivery system records, the weapon states could take similar steps regarding their fissile material production and lay the basis for declaring:

- Shutdown fissile material production facilities, the state of shutdown, and their decommissioning or conversion plans; and

- HEU and plutonium production and related waste production and disposal records.

Finally, by the 2015 NPT Review Conference, the weapon states could agree to pursue new cooperative projects, where possible with IAEA participation, to develop and demonstrate approaches that could allow verification of all these declarations. Russia and the United States are currently conducting inspections at strategic nuclear weapon deployment sites and related facilities.

It will be particularly important to develop approaches for verifying warhead dismantlement. This would provide confidence that warheads have been destroyed as part of arms control agreements and assurance that the fissile material contained in the warheads was recovered and accounted for.

To permit verification of declarations of historical fissile material production would require access to former fissile material production sites, operating records and waste materials. To make this possible, weapon states should as soon as possible:

- Catalogue and preserve operating records and waste materials.

States also could pursue cooperative projects to develop the methods of "nuclear archaeology," which uses nuclear-forensic analysis of samples from structural or waste materials to obtain evidence relating to the operating history of nuclear production facilities. These include:

- Dedicated plutonium production reactors;

- High-level waste from military reprocessing plants;

- Gaseous diffusion, electromagnetic, and centrifuge uranium enrichment facilities that were used for HEU production; and

- Depleted uranium stored at enrichment facilities.

Since former production facilities are mostly shutdown, priority for nuclear archaeology projects should be given to facilities being prepared for decommissioning and for waste materials scheduled for elimination or processing for long term storage that may erase critical information.

The subsequent five chapters treat some of these issues in greater detail, providing where appropriate the policy and technical underpinning for the relevant proposals.

Chapter 3 reviews the long-standing and increasingly detailed demands for nuclear weapon state transparency that have emerged from the United Nations and the NPT parties, the steps taken in this direction by the five NPT nuclear weapon states as well as the initiatives by non-weapon states. It also includes some of the key efforts that emerged from outside the United Nations and NPT structures, from U.S.-Russian bilateral agreements to proposals by non-governmental organizations.

All nuclear weapon states historically have attached great importance to maintaining secrecy about their warhead stockpiles. Some states have started to lift this secrecy since the end of the Cold War. Over the past two decades, some states have been more open about their nuclear histories, and independent analysts have developed considerable insight into nuclear weapon programs. Chapter 4 summarizes current publicly available information about national nuclear warhead stockpiles as well as the recent transparency record of the nuclear weapon states. It includes proposals for how weapon states could be more transparent about their nuclear arsenals.

The United States has been the most transparent among the nuclear weapon states in making public information about its nuclear warhead stockpile and its production and stockpiles both of HEU and plutonium. The United States has released detailed declarations, with updates, of its fissile material stockpiles. The plutonium declaration covering the period 1944 to 1994 was released in 1996, and updated in 2012 to cover the period up to 2009; the HEU declaration for the period 1944 to 1996 was completed in 2001 and publicly released in 2006, it was updated in 2006 to cover the period up to 2004. Chapter 5 describes the challenges of producing these fissile material declarations, explaining how the declarations were made and why, and what lessons other weapons states considering fissile material declarations may learn from the U.S. experience. The lessons include the importance of organizing and archiving all the information used to construct the declarations, and the value of binding commitments to transparency and reporting for overcoming political and institutional barriers to making declarations.

Chapter 6 provides a detailed study of the origin of the annual declarations of civilian plutonium holdings that have been made since 1997 by nine countries (Belgium, China, France, Germany, Japan, the Russian Federation, Switzerland, the United Kingdom, and the United States)—known as the "Guidelines for the Management of Plutonium" and published each year by the IAEA as INFCIRC/549. It describes the origins of the Guidelines, and the negotiations that led to the adoption of its various provisions, and why HEU was excluded. The chapter offers proposals for how the plutonium Guidelines could be enhanced to bolster transparency and be broadened to include HEU (the United Kingdom, Germany, and France declare civilian HEU as part of the INFCIRC/549 declarations) and how weapon states could make declarations to cover fissile material in weapon programs.

The final chapter traces the experience of U.S.-Russian cooperation in developing approaches and tools for nuclear warhead verification and for nuclear archaeology. It demonstrates the success of research and development efforts in the areas of cooperatively monitoring nuclear warheads and their dismantlement and in reconstructing plutonium production histories in some kinds of production reactors. It concludes that successful development of nuclear weapon and fissile material verification procedures and technologies will likely require more such collaborative R&D efforts and may be carried out on a bilateral or multi-lateral basis between weapon states as well as non-nuclear weapon states. In particular, the chapter stresses that weapon states will need to rethink what information needs to be treated as secret since secrecy is a fundamental obstacle to verification.

# 1 Nuclear Weapon and Fissile Material Stockpiles and Production

At the end of 2012, the global stockpile of highly enriched uranium (HEU) was about 1380 ± 125 tons*, enough for more than 55,000 simple, first-generation fission implosion weapons. About 98% of this material is held by the nuclear weapon states, with the largest HEU stockpiles being held by Russia and the United States. The large uncertainty in the estimate is due to Russia not declaring how much HEU it produced before stopping production in the late 1980s. The United States, which ended production in 1992, has published an official history of its HEU production.

The global HEU stockpile has been shrinking for the past two decades as Russia and the United States have been blending down HEU that they have declared as excess to military needs at a combined rate of over 30 tons per year to produce low-enriched uranium for power reactor fuel. Today, only Pakistan and possibly India are believed to be producing HEU for weapons purposes. But their programs are relatively small scale. It remains uncertain whether North Korea has been producing HEU using the centrifuge enrichment capability that it revealed in 2010. In 2012, Russia announced that it will restart HEU production in an existing enrichment plant justifying this step by the need for icebreaker and research reactor fuel.

In 2012, the United States withdrew 24 tons of HEU from its stockpile of material declared excess for military purposes and earmarked for blend-down; this material is now reserved for naval fuel, bringing the total amount of HEU in this category from 128 tons to 152 tons of (fresh) weapon-grade HEU.

The non-nuclear weapon states account for an estimated 15 tons of HEU, almost all of which was provided to them as research reactor fuel by the weapon states. This stockpile is declining as research reactors are closed down or converted to low-enriched uranium fuel and fresh and spent HEU fuel is returned to the country of origin.

The global stockpile of separated plutonium in 2012 was about 495 ± 10 tons. About half of this stockpile was produced for weapons, while the other half has mostly been separated in civilian programs in nuclear weapon states, some of it for foreign customers. As a result, about 98 per cent of all separated plutonium is stored in the nuclear weapon states. There are about 11 tons of plutonium in the non-weapon states, most of which is in Japan, the only non-weapon state with a large program to separate plutonium from spent nuclear fuel.

* Throughout this report, tons refer to metric tons. One metric ton corresponds to 1000 kg or about 2205 pounds.

The disposal as waste of 4.4 tons of U.S. excess plutonium has meant the global stockpile of separated plutonium for weapons has not increased despite continued production in Israel, India and Pakistan. The other nuclear weapon states have ended production, in most cases decades ago.

**Nuclear Weapon Stocks**

There are today nine nuclear weapon states: in historical order, the United States, Russia, the United Kingdom, France, China, Israel, India, Pakistan, and North Korea. The first four of these states have been reducing their deployed arsenals from Cold War levels. China and Israel, the fifth and sixth states respectively to make nuclear weapons, did not produce such large weapon stockpiles, and they are believed to have kept their arsenals roughly constant for the past few decades. India and Pakistan, which carried out their first nuclear tests in 1974 and 1998 respectively, are building up their weapon stockpiles. North Korea, which carried out its third nuclear test in February 2013, also may be building up its arsenal if it has started producing HEU for weapons and has resumed plutonium production.

Estimates of the current nuclear-weapon stocks held by the nine nuclear weapon states as of the end of 2013 are shown in Table 1.1 For further discussion of national nuclear warhead stockpiles, see Chapters 2 and 4 of this report.

| Country | Current Nuclear Warheads |
|---|---|
| United States | ~ 7700, with about 3000 awaiting dismantlement |
| Russia | ~ 8500, with about 4000 awaiting dismantlement |
| France | fewer than 300 |
| China | ~250 |
| United Kingdom | fewer than 225 |
| Israel | 100 – 200 |
| Pakistan | 100 – 120 |
| India | 90 – 110 |
| North Korea | fewer than 10 |

**Table 1.1. Estimated total nuclear-weapon stockpiles, 2013.** *Source: Federation of American Scientists.*[1]

***United States and Russia.*** Under the terms of the U.S.-Russia New START Treaty, which entered into force in 2011, each country commits to reduce the number of its deployed strategic warheads to 1550 weapons by the year 2018 (for details, see Chapter 2). Under the terms of the Treaty, warheads that are removed from deployment do not need to be dismantled. In early 2013, the United States indicated that it would seek agreement with Russia on further reductions in nuclear weapons, with a possible goal of 1000 – 1100 deployed strategic warheads.[2]

As part of nuclear arms reduction talks with Russia, the United States is seeking "discussions with Russia on a step we have never taken before—reducing not only our strategic nuclear warheads, but also tactical weapons and warheads in reserve."[3] The United States has about 2500 nuclear warheads in reserve and an estimated additional 3000 intact warheads awaiting dismantlement.[4] Russia has an estimated 2700 warheads in storage, about 2000 of which are believed to be tactical weapons, and about 4000 warheads waiting to be dismantled.[5]

***United Kingdom.*** The United Kingdom revealed that since 2002 it has been dismantling some of the nuclear warheads that are being withdrawn from service as part of its planned reduction of its arsenal to no more than a total of 180 warheads by the mid-2020s.[6] It is estimated that the United Kingdom may be dismantling about three warheads per year at the Atomic Weapons Establishment Burghfield site, which is also responsible for assembling and refurbishing warheads.[7] Warheads withdrawn from service and awaiting dismantlement are stored at the Royal Naval Armaments Depot Coulport in Scotland.

For other developments in the past year concerning the nuclear weapon stocks of the nuclear weapon states, see Chapter 4.

***North Korea.*** On 12 February 2013, North Korea carried out a nuclear weapon test.[8] It was detected seismically at the time and later by radionuclides (xenon isotopes) released from the test that were picked up by monitoring stations in Japan and Russia.[9] Radionuclides from North Korea's first test, in 2006, were collected by detectors that are part of the Comprehensive Test Ban Treaty verification system and suggested that the fissile material used was plutonium. In 2009, a second nuclear test was detected seismically but produced no radionuclide signature. Radionuclides collected in South Korea, Japan, and Russia in May 2010 have led to a suggestion of a possible additional undeclared test of very low yield.[10]

### Highly Enriched Uranium

The current global inventory of HEU is estimated to be about 1380 ± 125 tons. About 98% of this material is held by the nuclear weapon states, and most of it belongs to Russia and the United States. The large uncertainty is due to a lack of accurate public information about Russian HEU production and consumption (for details, see *Global Fissile Material Report 2010)*. A Russian declaration of its HEU production, which ended 25 years ago, in 1987–1988, would be a major step forward in improving estimates of the global HEU stockpile.

The United States and United Kingdom have declared the size of their HEU stockpiles, and France declares its civilian HEU stockpile. The other nuclear weapon states release no information on their HEU holdings. Pakistan and India, and possibly North Korea are currently the only states producing HEU. North Korea in 2010 disclosed a uranium enrichment centrifuge plant, but it is not known whether this plant, or a possible second enrichment plant, is producing HEU.

The global stockpile of HEU is declining as Russia and the United States blend down HEU declared as excess for weapons and military purposes into low-enriched uranium (LEU) for use as fuel in power reactors.

***Russia.*** Russia has the largest HEU stockpile of any state. As of the end of 2012, Russia has an estimated 695 ± 120 tons of highly enriched uranium. This includes material in and available for weapons, and reserved for naval and research reactor fuel. This amount is what remains of 1250 ± 120 tons of 90%-enriched HEU that Russia is estimated to have produced.[11] The very large uncertainty in the estimate is due in large part to a lack of public information about the operating histories and capacities (including plant modernization and upgrades) and composition of uranium-bearing wastes of the Soviet-era gaseous diffusion and centrifuge enrichment plants (for details see *Global Fissile Material Report 2010*).

As of the end of December 2012, Russia had down blended to LEU a total of 473 tons of excess weapon-grade HEU it agreed to sell to the United States.[12] This leaves a further 27 tons of HEU to be down-blended during 2013 to fulfill the 1993 agreement to down-blend 500 tons of excess weapons HEU. Delivery of the final material for the program is expected in November 2013.[13]

A second, much smaller Russian HEU down-blending effort, the Material Conversion and Consolidation (MCC) program, funded by the United States, covers excess non-weapons HEU. It aims to eliminate 17 tons of HEU by 2015. As of the end of 2012, the program had down-blended about 15 tons of HEU.[14]

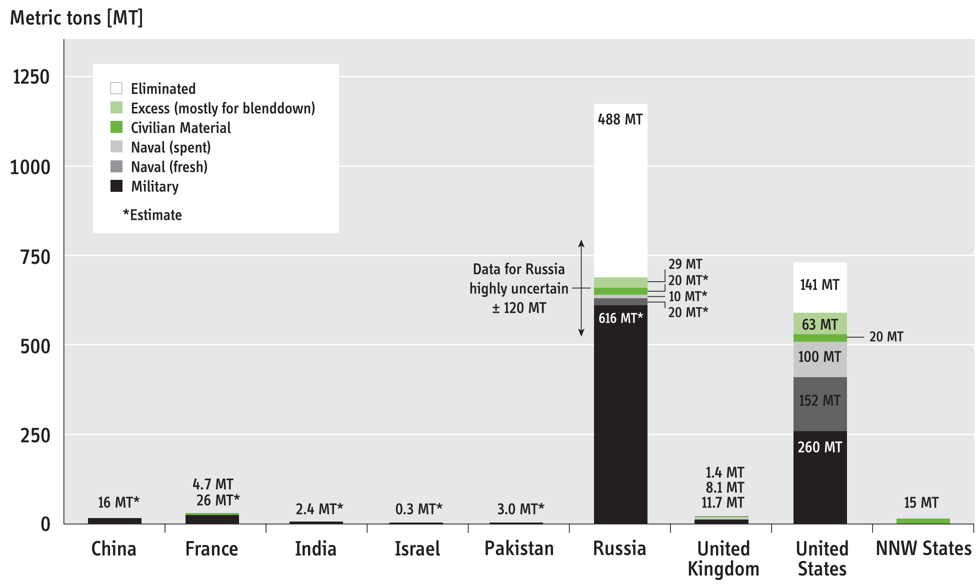


**Figure 1.1. National stocks of highly enriched uranium as of 2012.** The numbers for the United Kingdom and United States are based on official publications and statements. The civilian HEU stocks of France and the United Kingdom are based on their public declarations to the IAEA. Numbers with asterisks are IPFM estimates, often with large uncertainties. A 20% uncertainty is assumed in the figures for total stocks in China and for the military stockpile in France, about 30% for Pakistan, and about 40% for India. The 488 tons of eliminated Russian HEU include 473 tons from the 500-ton HEU deal and 15 tons from the Material Consolidation and Conversion project. HEU in non-nuclear weapon (NNW) states is under IAEA safeguards. About 10 tons of the HEU in non-nuclear weapon states is irradiated fuel in Kazakhstan with an estimated enrichment of about 20%.

***United States.*** The total U.S. HEU stockpile is estimated as 595 tons, as of the end of 2012. In 2006, the United States declared that, as 30 September 2004, a total of about 690 tons of HEU remained from the 850 tons of HEU it had produced or acquired since 1945.[15] The stockpile is declining because of the continuing blend-down of 210 tons of HEU declared as excess to military requirements.

Through the end of 2012, approximately 141 tons had been down-blended.[16] The HEU down-blending rate has slowed from about 10 tons per year to 3–4 tons per year. Down-blending of the remaining U.S. HEU already declared excess is planned to take at least until 2050.[17] According to the U.S. Department of Energy, “a review of surplus HEU material that will be available in the next several years shows a relatively small supply to initiate a new down-blend contract offering."[18]

The excess HEU expected to be available for down blending has decreased by about 24 tons. On 29 April 2011, the U.S. National Nuclear Security Administration stated that, "based on historical data, DOE anticipated that up to approximately 32 tons of the [160 tons designated for naval reactor fuel] HEU might be unsuitable for use as naval reactor fuel, and proposed to down-blend rejected material to LEU."[19] Since then, the Navy has found unsuitable only 8 tons of this 160 tons of excess HEU.[20] Accordingly, the amount of HEU reserved for U.S. naval fuel has increased from 128 tons to 152 tons—and the amount of excess U.S. HEU decreased by the same amount, i.e., by 24 tons.

Questions were raised about the security of the U.S. HEU stockpile in July 2012, when three antinuclear activists penetrated the high security system surrounding the newly built Highly Enriched Uranium Materials Facility (HEUMF) at the Y-12 site in Tennessee, which contains over 100 tons of HEU.[21] All nuclear operations at Y-12 were shutdown for some time. An official investigation found that:[22]

> "the Y-12 security incident represented multiple system failures on several levels. For example, we identified troubling displays of ineptitude in responding to alarms, failures to maintain critical security equipment, over reliance on compensatory measures, misunderstanding of security protocols, poor communications, and weaknesses in contract and resource management. Contractor governance and Federal oversight failed to identify and correct early indicators of these multiple system breakdowns. When combined, these issues directly contributed to an atmosphere in which the trespassers could gain access to the protected security area directly adjacent to one of the Nation's most critically important and highly secured weapons-related facilities."

***United Kingdom.*** The United Kingdom has a HEU stockpile estimated as about 21.2 tons of HEU. In 2006, the United Kingdom declared that, as of 31 March 2002, it had a stock of about 21.9 tons of HEU.[23] The United Kingdom has not declared how much of this HEU it produced domestically, however. It is estimated that perhaps more than half of the current UK HEU stockpile is of U.S.-origin, provided under their bilateral 1958 Mutual Defense Agreement. The two HEU declarations by the United States do not report the total amount of HEU transferred to the United Kingdom, treating this data as classified.

It is estimated that by 2012 about 0.7 tons of this HEU may have been consumed through fission in the UK's nuclear powered attack submarines and ballistic-missile submarines.[24] The United Kingdom also has declared that 1.4 tons of its HEU is civilian, as of the end of 2011.[25]

***France.*** France has not officially declared its total HEU stockpile. It has declared to the IAEA, however, a civilian HEU inventory of 4.7 tons as of 31 December 2012, which includes French HEU and HEU received from the United States and Russia for research reactor fuel.[26] France ended production of HEU in 1996 and has dismantled the Pierrelatte gaseous diffusion enrichment plant that was used for the production of weapon-grade uranium.[27]

There is significant uncertainty about the production and current stockpile of HEU in France. Its current inventory of military HEU has been previously estimated as 26 ± 6 tons.[28] A recent analysis offers grounds for a significantly lower estimate of the stockpile of weapon-grade HEU, however, based on evidence the Pierrelatte enrichment plant may have had both a much shorter effective period of operation and a lower weapon-grade HEU production capacity than previously assumed.[29]

Despite Pierrelatte's HEU production operation of about 30 years (1967–1996), it operated only on a seasonal basis (from April to October) after the Eurodif enrichment plant came on-line in 1984, resulting in a reduced lifetime capacity equivalent to about 23 effective full-production years.[30] It is unclear whether or not France compensated for this by upgrading the diffusion barriers and compressors in UTH (usine très haute, very-high plant), the Pierrelatte unit that produced weapon-grade HEU from 25%-enriched feed material.[31] There were significant upgrades at gaseous diffusion plants in the United States, the Soviet Union (1958–1962), the United Kingdom (1956–1959), and China (1970s), in some cases allowing an effective doubling of capacity.[32]

Public information on the separation factor for early French gaseous diffusion barriers (i.e., assuming no upgrades), the number of stages of UTH (1150 stages), and the flow rate in UTH, suggests a production rate of 580 kg per year of weapon-grade HEU. This is consistent with the original target rate of 600–700 kg per full-production year and implies a cumulative production of 14–16 tons of weapon-grade HEU at Pierrelatte.[33] Subtracting an estimated 9 ± 2 tons of HEU consumed in tritium and plutonium production reactors and nuclear weapon tests, France's current inventory would be on the order of 6 ± 2 tons. This is much lower than previous estimates. If the barriers were upgraded at the time of the move to seasonal operation so as to maintain the target HEU production rate, however, the plant could have continued production at almost 600–700 kg per year for the rest of its lifetime. In this case, estimated total production would amount to about 18–21 tons of HEU, with a current stockpile of 10 ± 2 tons of HEU.

The significant uncertainty about France's HEU production and stockpile highlights the value of an official French fissile material production history and stockpile declaration on the model of the declarations by the United Kingdom and United States.

***China.*** China may have a stockpile of about 16 ± 4 tons of HEU; an additional 4 tons of HEU may have been consumed in nuclear-weapon tests and in research reactor fuel.[34] China produced its HEU at the Lanzhou gaseous diffusion enrichment plant from 1964 to 1980, and at the Heping plant from 1975 to 1987.

The large uncertainty in the HEU estimate is due to a lack of accurate public information about the capacity and operating history of China's enrichment plants. China does not release any information on its HEU stockpiles and has not declared any of its HEU as civilian.

***India.*** India's HEU production is believed to be aimed mostly at producing fuel for the reactors for the Arihant-class nuclear-powered ballistic missile submarines that India is building. India is estimated to have a stockpile of 2.4 ± 0.9 tons of HEU as of the end of 2012.[35] This estimate assumes India's naval fuel is enriched to 30%, i.e., significantly below the 90% typically used in nuclear weapons.[36] The naval reactor power is estimated at 80 MW-thermal and each reactor core is taken to contain about 65 kg of uranium-235.

The INS Arihant submarine reactor went critical for the first time in August 2013.[37] It is undergoing sea trials. A second Arihant-class nuclear submarine (INS Aridaman) is under construction, and work on a third submarine is at an early stage.[38] Plans call for the Arihant submarines to carry twelve K-15 submarine-launched ballistic missiles with a range of 700 km for nuclear weapons delivery. There is also a land-based prototype of the Arihant submarine reactor that is being used "for training operators and maintenance personnel."[39]

India enriches its uranium at the Rare Materials Plant (RMP) in Rattehalli, Karnataka. It is expanding its uranium enrichment capacity at the site and also has started construction of a second enrichment facility, the "Special Material Enrichment Facility," in Chitradurga, Karnataka. The Chairman of India's Atomic Energy Commission has stated that the new facility will be built in several phases and that the enriched uranium will be used for "higher burn-up fuels" for pressurized heavy-water reactors as well as light-water reactors.[40]

***Pakistan.*** Pakistan continues to produce HEU for its nuclear weapon program. Estimates are limited by the uncertainty about Pakistan's enrichment capacity, and the operating history of its centrifuge plant at Kahuta and possibly a second plant that reportedly exists at Gadwal.[41]

It is estimated that, as of the end of 2012, Pakistan could have produced about 3 ± 1.2 tons of weapon-grade HEU. An additional 0.1 tons may have been consumed in Pakistan's six nuclear weapon tests in 1998.

***North Korea.*** There continues to be uncertainty about possible HEU production in North Korea. In late 2010, North Korea revealed a uranium enrichment plant at the Yongbyon site containing an estimated 2000 centrifuges similar to Pakistan's P-2 machines.[42] North Korea claims the enrichment plant, while not safeguarded, is civilian and intended to produce LEU to fuel a light-water reactor being built at the site.

The possibility that North Korea was working on uranium enrichment first surfaced in 2002, with a November 2002 declassified CIA assessment that "North Korea was constructing a plant that could produce enough weapons-grade uranium for two or more nuclear weapons per year when fully operational—which could be as soon as mid-decade."[43] Pending further information about this program, North Korea continues to be assigned a zero stockpile of HEU.

### Civilian Use of HEU

Along with its use in nuclear weapons and military naval propulsion, HEU is used in many countries as reactor fuel in civilian research reactors and other facilities. There are about one hundred civilian facilities worldwide that use HEU, some of which contain large quantities of HEU.[44] HEU also is used to fuel 11 propulsion reactors in seven Russian civilian icebreaker and container ships. As of December 2012, 33 countries had at least 1 kg of highly enriched uranium in their civilian stocks.[45]

The United States and Russia exported HEU-fueled research reactors to other countries as part of their respective Atoms for Peace programs. The United States exported about 17.5 tons of HEU as fuel for these reactors.[46]

The U.S. Global Threat Reduction Initiative is charged with securing and removing U.S.-origin HEU at civilian sites in other countries and is working with Russia to do the same in countries supplied with HEU fuel by the Soviet Union and Russia. As of the end of 2012, HEU has been removed from 24 countries, with 18 of these countries having been cleared out of all U.S.-origin HEU.[47]

The HEU fueled high-flux research reactor (PIK) that Russia is constructing in Gatchina, near St.-Petersburg, continues to be delayed. Construction of the reactor began in 1976. The reactor went critical in February 2011, but the start of operations at full power has been delayed several times. The date of start-up is expected to be determined at the end of 2013.[48] Once operational, the PIK reactor could require on the order of 100 kg of weapon-grade HEU per year.

***Non-weapon-states.*** In its most recent annual report, the IAEA reports that there were 213 "Significant Quantities" of HEU under comprehensive safeguards (i.e., in non-weapon states) as of 31 December 2011.[49] This is estimated to be equivalent to about 15 tons of HEU.[50] This includes about 10 tons of HEU with average enrichment of about 20% in the form of spent fuel from the BN-350 reactor in Kazakhstan, which was shut down in 1999.[51]

### Civilian Uranium Enrichment Plants

In 2012, civilian enrichment plants in ten countries produced low-enriched uranium for power-reactor fuel (see Appendix 1.1). The number and capacities of these civilian enrichment plants is growing. In November 2010, North Korea revealed a small centrifuge enrichment plant in its Yongbyon nuclear complex that it claimed as civilian.

***United States.*** Urenco USA's centrifuge plant (the National Enrichment Facility) in Eunice, New Mexico, which began operating in June 2010, reached a capacity of about 2 million SWU/yr by the end of 2012. The target capacity is 5.7 million SWU/yr in 2015.[52] A request has been filed for a license amendment to allow the annual enrichment capacity at the facility to increase to 10 million SWU/yr by 2020.[53] Part of the capacity expansion will involve installing more powerful TC-21 centrifuges rather than adding more of the TC-12 centrifuges currently in use at the plant.[54]

Other plans for expansion of centrifuge uranium enrichment capacity in the United States over the coming decade started to unravel in 2012. Construction of AREVA's Eagle Rock Enrichment Facility, at Idaho Falls, Idaho, continued to face delays. Construction on this centrifuge plant had been planned to start in 2012, with first production of LEU in 2014. In February 2012, however, URS Nuclear LLC, the Procurement and Construction Manager for the project, notified all of its subcontractors that the "project has been placed on indefinite suspension until further notice."[55] AREVA now expects construction to start possibly in 2014 if it can find a financial partner to share the cost of the project.[56] AREVA is seeking an additional $1 billion to finance the project.[57] The Eagle Rock plant received a $2 billion loan guarantee from the U.S. government in 2010.

The American Centrifuge Plant at Piketon, Ohio, proposed by the U.S. Enrichment Corporation (USEC, which operated the U.S. government-owned Paducah gaseous diffusion plant), continues to face technical and financial difficulties. USEC has so far failed to secure the $2 billion loan guarantee it has been seeking from the U.S. government for the project. It is currently negotiating with the U.S. Department of Energy for $300 million to support a technology research, development, and demonstration program.[58]

In September 2012, the U.S. Nuclear Regulatory Commission (NRC) issued a construction and operating license for the Global Laser Enrichment (GLE) plant proposed by

General Electric (United States), Hitachi (Japan) and Cameco (Canada), in Wilmington, North Carolina.[59] GLE announced in 2013 that it intends a two-year effort to build and test "a first set" of commercial-scale equipment and then consider a decision on construction of the facility.[60] Plans call for the facility to be able to enrich up to 8% uranium-235 and for the enrichment capacity to increase by one million SWU per year in its first six years to a final capacity of 6 million SWU/yr.[61] A number of concerns have been raised about the proliferation implications of the production-scale demonstration and commercialization of laser enrichment technology but the NRC declined to do a nonproliferation assessment prior to approving the license.[62]

In May 2013, USEC announced the end of enrichment operations at the Paducah gaseous diffusion plant in Kentucky, the last operating plant of this kind in the United States.[63] The plant began operating in 1952. USEC explained that the reasons for the closure was that the Paducah plant was inefficient compared with the centrifuge plants being operated by its competitors, and that demand for enriched uranium had declined with the shutdown of nuclear power reactors in Japan and Germany.[64] The site will revert to its owner, the U.S. Department of Energy.

The demolition of the Manhattan project era K-25 gaseous diffusion enrichment plant, in Oak Ridge, Tennessee, is expected to be completed in 2014 (Figure 1.2).[65] Demolition began in 2008 and is to cost over $1 billion.[66]

**Figure 1.2. Demolition of the K-25 gaseous diffusion enrichment plant.** Built between June 1943 and 1945 as part of the Manhattan Project, demolition of the four-story, U-shaped half-mile long K-25 plant is expected to be completed in 2014.[67] The picture on the left was taken September 2012 and the one on the right is from January 2013. *Source: UCOR.*

***Russia.*** In late 2012, the Electrochemical plant (EKhZ) in Zelenogorsk launched a centrifuge cascade that will be producing HEU for fast reactor and research reactor fuel.[68] The head of Russian Rosatom's fuel company TVEL Yuri Olenin suggested that "the need to produce HEU is linked to a number of new projects, in particular, related to icebreakers." Russia has excess weapons HEU that could have been used for this purpose. If carried through, this new HEU production for non-weapons purposes could have significant implications for the verification arrangements required for a Fissile Material Cutoff Treaty.

***China.*** China may have expanded the capacity at its indigenous centrifuge plant at Lanzhou, Gansu province to 1.0 million SWU/yr.[69] Operations at this plant began in 2010 with a capacity estimated as 0.5 million SWU/yr.[70] The capacity increase would take China's estimated total centrifuge enrichment capacity to 2.5 million SWU/yr, which is enough to support about 20 GWe of light-water reactor capacity. This includes 1.5 million SWU/yr of capacity at the Russian-supplied enrichment plants at Hanzhong (1 million SWU/yr) and at Lanzhou (0.5 million SWU/yr).

***France.*** At the end of 2012, the Georges Besse II (GB-II) centrifuge plant reached a capacity of 2.5 million SWU/yr.[71] The plant, which began commercial operations in April 2011, is scheduled to reach its design capacity of 7.5 million SWU/yr in 2016.[72] The plant uses TC-12 centrifuges developed by Enrichment Technology Corporation (ETC), which is jointly owned by URENCO and AREVA. The TC-12 is a carbon-fiber centrifuge with a capacity of 40 SWU/year (Figure 1.3); the TC-12 is the predecessor of the TC-21, which has an estimated capacity of about 100 SWU/yr.

In June 2012, Eurodif's Georges Besse gaseous diffusion enrichment plant at the Tricastin site ceased production, after operating for 33 years.[73] The plant is to be dismantled over a fifteen-year period starting in 2016.[74]

**Figure 1.3. George Besse II centrifuge cascade.** The TC-12 machines in use the plant are made of carbon-fiber and were developed in the 1990s. Each machine has an estimated capacity of about 40 SWU/yr compared to the more advanced TC-21 (100 SWU/yr). *Source: AREVA/Nicolas Petitot (with permission).*

***Iran.*** In early 2013, Iran announced that it is building about 3000 next-generation uranium enrichment centrifuges, with Fereydoun Abbasi-Davani, the head of Iran's Atomic Energy Organization, explaining that "the final production line of these centrifuges has reached an end and soon the early generations with low efficiency will be set aside."[75] Cascades of four different kinds of centrifuges have been installed in the research and development area of the Natanz pilot plant as of 2013.[76] According to the IAEA, Iran has been "intermittently" feeding uranium hexafluoride into these machines as single machines and sometimes as cascades.

***Japan.*** The Rokkasho centrifuge plant resumed limited operation in March 2012, producing 11 tons of LEU as of September 2012.[77] This would be equivalent to a capacity of 50,000–60,000 SWU/yr. The plant, belonging to Japan Nuclear Fuels Ltd. (JNFL), began operation in 1992 but problems with the centrifuges led JNFL to shut down the plant in December 2010.[78] Plans call for the plant to reach its design capacity of 1.5 million SWU/yr in 2020. Japan's fleet of 50 power reactors has been shut down since the Fukushima accident in March 2011; there is therefore currently no demand for enriched uranium to fuel domestic reactors.

***Argentina.*** No uranium enrichment was reported during 2012 for the Pilcanyeu gaseous diffusion enrichment plant, which was reopened in September 2010 and expected to begin producing low-enriched uranium by September 2011.[79] The plant operated from 1983 to 1989 with a capacity of about 20,000 SWU per year.

### Separated Plutonium

The global stockpile of separated plutonium is estimated as 495 ± 10 tons as of 2012. Russia and the United States have the largest stockpiles of plutonium produced for weapons. The United States has declared its history of production and use of weapons plutonium and provided an update in 2012 up to September 2009. The United Kingdom also has declared the size of its weapons plutonium stockpile in 2000 but has not updated the data or provided additional information since then.[80] The other nuclear weapons states have not made declarations of their fissile material production histories and use. There remain significant uncertainties in estimates of Russia's stockpile.

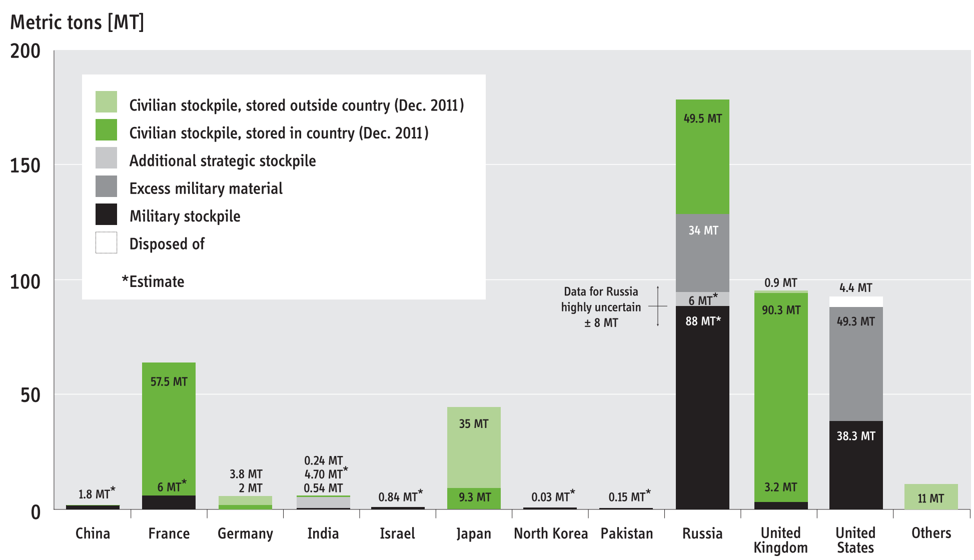


**Figure 1.4. National stocks of separated plutonium as of 2012.** Civilian stocks are based on the INFCIRC/549 declarations published in 2012, which report material as of 31 December 2011 and are listed by ownership, not by current location. Weapon stocks are based on IPFM estimates except for the United States and United Kingdom whose governments have made declarations. Uncertainties in estimated military stockpiles for China, France, India, Israel, Pakistan, and Russia are on the order of 10–30%. The plutonium India separated from spent heavy-water power-reactor fuel has been categorized by India as "strategic," and not to be placed under IAEA safeguards. Russia has 6 tons of weapon-grade plutonium that it has agreed to not use for weapons but not declared excess. The United States has disposed of 4.4 tons of excess plutonium as waste in its underground Waste Isolation Pilot Plant, in New Mexico.

The United Kingdom, France, and Russia, in that order, have the largest civilian plutonium stockpiles. Among the non-weapon states, Japan has the largest stockpile but its stockpile has not been growing. The future of Japan's reprocessing program is uncertain in the wake of the March 2011 nuclear disaster at Fukushima. The civilian plutonium stockpile will increase more rapidly if India and China go forward with their ambitious reprocessing programs. The United Kingdom is expecting to end its reprocessing program when its existing reprocessing contacts are completed, which is currently projected for 2018. Appendix 1.2 lists operating reprocessing plants as of 2013.

#### Weapons Plutonium

***United States and Russia.*** Under the amended bilateral U.S.-Russia Plutonium Management and Disposition Agreement (PMDA), which entered into force in July 2011, the two countries commit to dispose of 34 tons each of excess weapons plutonium by turning it into mixed oxide (MOX) fuel and using it in nuclear power reactors.[81] Under the PMDA, the disposition is to begin in 2018. The program is facing problems in the United States.

***United States.*** In June 2012, the United States published *The United States Plutonium Balance, 1944–2009*, a declaration of its historical production, consumption, and losses to waste updated to 30 September 2009.[82] The previous declaration, published in 1996, covered the period up to 30 September 1994.[83] For a comparison of the two declarations, see Chapter 5.

In the updated declaration, the United States reported a plutonium stock of 95.4 tons as of 30 September 2009. This is a reduction of 4.1 tons from the total quantity of 99.5 tons declared for the end of September 1994. Most of this reduction in the stockpile is due to removal from the accounts of plutonium in waste that was sent for disposal in the underground Waste Isolation Pilot Plant (WIPP) in New Mexico, which opened in 1999.

The updated declaration lists 9.7 tons of U.S. plutonium as estimated to be in waste, an increase of 5.8 tons from the declared inventory in waste (3.9 tons) as of 1994. The increase was attributed in large part to classification as waste of plutonium that previously had been marked for recovery and an increase in estimates of the amount of plutonium present in existing wastes.

In its annual INFCIRC/549 report to IAEA about its plutonium stockpile, the United States lists as civilian its excess plutonium (described as plutonium surplus to defence needs) even though this material is not under IAEA safeguards. In its 2012 INFCIRC/549 report, the United States declared a stockpile of 49.3 tons of unirradiated excess weapon plutonium, as of the end of December 2011.[84] This marks a reduction of 4.6 tons of excess plutonium compared to the inventory for the end of December 2010. The declaration notes that 4.4 tons of this plutonium is material disposed as waste in WIPP since 1998. The remaining reduction of 0.2 tons in the reported quantity is due to an increase in the amount of plutonium estimated to be still in spent fuel from government-owned reactors.

In August 2012, the U.S. Department of Energy completed the first shipment of weapon-grade plutonium from the Savannah River Site (SRS) to WIPP in New Mexico. The shipment included 5 kg of non-pit plutonium that was deemed to be not suitable to make into MOX. The plutonium was mixed with inert material and packaged into 35 shipping drums.[85] This kind of direct disposal of weapon-grade plutonium into an underground repository may offer an alternative way of disposing of the excess weapons plutonium that the United States currently plans to fabricate into MOX.[86] There is currently no international verification of this form of plutonium disposal.

After long delays and large increases in estimated costs, the United States is reconsidering its plan to dispose of its 34 tons of excess plutonium by fabricating it into MOX fuel for light water reactors.[87] The Department of Energy budget request for 2014 cuts the request for funding for the MOX plant, noting that the "current plutonium disposition approach may be unaffordable… due to cost growth and fiscal pressure" and announced that the United States "will assess the feasibility of alternative plutonium disposition strategies."[88] The MOX facility, which is under construction at the Savannah River Site in South Carolina, is now projected to cost almost $7.7 billion and be ready to begin operation in 2019.[89] The National Nuclear Security Administration, which is responsible for the MOX plant, had originally estimated in 1997 that it would cost about $1.4 billion and be completed by September 2004.[90]

***Russia.*** Russia has ended reprocessing of plutonium production reactor fuel at its Seversk and Zheleznogorsk reprocessing plants; the last batch of fuel was loaded in March 2012.[91] The fuel came from the now shut-down ADE-2 reactor at Krasnoyarsk (Figure 1.5) and its counterparts, ADE-4 and ADE-5 in Seversk, which produced an estimated 15 tons of weapon-grade plutonium since 1994, which Russia committed not to use for weapons. Russia began decommissioning of the Seversk plutonium production reactors in 2012. Russia has a stockpile of weapons plutonium estimated as about 128 ± 8 tons.[92]

**Figure 1.5. The shutdown of the ADE-2 reactor in Zheleznogorsk, Russia.** Plutonium production for weapons ended in 1994, but the reactor continued to operate till 2010 to provide electricity and heat for the city. *Source: U.S. Department of Energy.*

The reprocessing plant at Seversk is also shut down.[93] The Zheleznogorsk reprocessing plant is shut down and will become a center for testing reprocessing of LWR spent fuel and for MOX-fuel production.[94] Russia has announced plans for a new pilot reprocessing plant at Zheleznogorsk.[95]

***China.*** China is estimated to have an inventory of 1.8 ± 0.5 tons of weapon-grade plutonium. It produced 2 ± 0.5 tons of plutonium for weapons, of which about 0.2 tons was consumed in its nuclear tests.

***Israel.*** The stock of plutonium produced for weapons is estimated to be 0.84 tons, assuming a production rate of 20 kg per year at Dimona.[96]

***India.*** India currently produces weapon-grade plutonium at the 100 MWt Dhruva reactor at the Bhabha Atomic Research Centre (BARC), in Mumbai. During the last year, the reactor was reported to have operated with an availability factor of over 70%.[97] The spent fuel from this reactor is reprocessed at the Trombay reprocessing plant in the same complex, which has a maximum capacity of 50 tons of spent fuel per year. As of the end of 2012, India is estimated to have a net stockpile of weapon-grade plutonium of 0.54 ± 0.18 tons. Two new production reactors, with power levels of 125 MWt and 30 MWt, are in the early stages of planning.[98] In December 2010, India shut down its 40 MWt CIRUS production reactor after fifty years of operation. The reactor was used to produce plutonium for India's nuclear test in 1974.

***Pakistan.*** Pakistan has a stockpile of about 0.15 ± 0.05 tons of weapons plutonium as of the end of 2012. This has been produced at the 40–50 MWt Khushab-I and Khushab-II reactors, which have been operating since 1998 and late 2009 or early 2010 respectively. Two additional production reactors are under construction at the Khushab site and are expected to come on-line in the near future.

### Civilian Plutonium

The global civilian plutonium stockpile is better understood than the military stockpile. Since 1997, nine countries (Belgium, China, France, Germany, Japan, Russia, Switzerland, the United Kingdom, and the United States) have been declaring annually and publicly their stocks of civilian plutonium to the IAEA (posted on the IAEA's website in the INFCIRC/549 series). A few additional non-weapon states (e.g. Italy and the Netherlands) also have civilian plutonium stockpiles, typically stored outside the country, but are not submitting INFCIRC/549 declarations.[99]

The INFCIRC/549 declarations give stocks of unirradiated plutonium at reprocessing plants, fuel-fabrication plants, reactors, and elsewhere, plus estimates of plutonium in spent fuel. For more on the declarations, see Appendix 1.3 to this chapter and Chapter 6 for a discussion of the origin of the declaration and suggestions on how they might be improved.

***United Kingdom.*** The United Kingdom includes in its annual INFCIRC/549 declaration of civilian plutonium the 4.4 tons of plutonium declared surplus for military requirements. This material has been placed under European Atomic Energy Community (EURATOM) safeguards and designated for IAEA safeguarding. UK surplus plutonium at Aldermaston was transferred to Sellafield (and put under safeguards) in several shipments. The first took place in 1999 and the last in 2002. The material was included in the INFCIRC/549 declarations for the years concerned upon receipt at Sellafield.[100]

In July 2012, the UK Nuclear Decommissioning Authority (NDA) announced the planned closure by 2018 of its THORP reprocessing plant, at Sellafield, when it is expected to complete its current reprocessing contracts.[101] THORP, which started operating in 1994, was originally expected to have completed these contracts in 2010.[102] The NDA noted, however, that "operational difficulties could result in the reprocessing of less than the currently planned amount of spent fuel by late 2018, the date by when reprocessing in THORP is expected to be completed."[103] The annual throughput of spent fuel at THORP is shown in Figure 1.6.

***China.*** In its civilian plutonium declaration for December 2011, China declared a total stock of 13.8 kg of unirradiated separated plutonium, in storage at a reprocessing plant.[104] This figure is unchanged from the civilian plutonium holdings for December 2010, while China's plutonium declarations for the previous years reported no stockpile. This plutonium was separated at China's pilot reprocessing plant, which completed hot tests at the end of 2010. The lack of any increase in the reported civilian plutonium stockpile suggests the plant did not operate in 2011. The plant is located in Gansu Province and has a reported capacity of 50–60 tons of spent fuel per year that can be expanded to 100 tons per year.

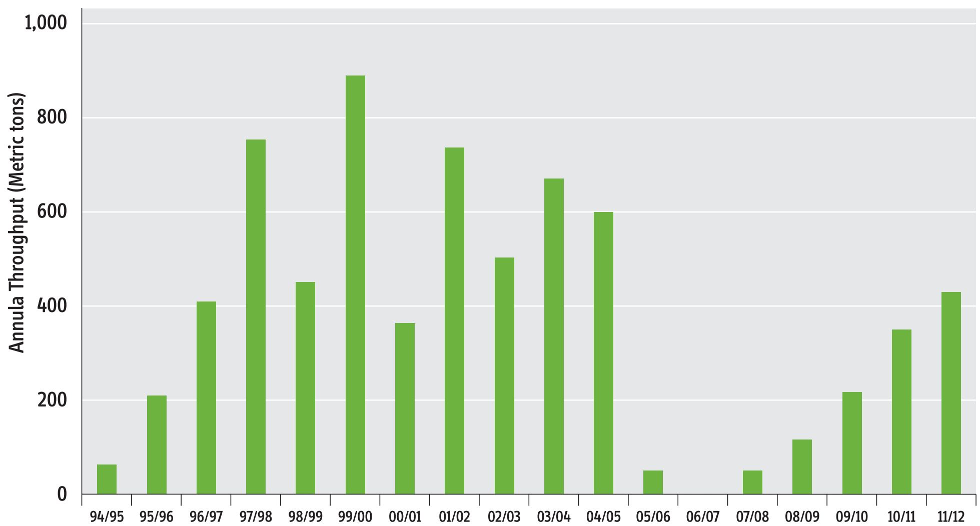


**Figure 1.6. Annual throughput of spent fuel at the UK THORP reprocessing plant.** The plant reprocessed a total of 6858 tons of spent fuel as of 2012. The target for 2012–2013 is 408 tons. The plant has a design capacity throughput of 1200 tons per year. Construction of THORP was completed in 1992. It is planned for shutdown when it completes its current contracts—estimated to be in 2018.

***India.*** India now operates three plants for reprocessing spent fuel from power reactors (pressurized heavy water reactors): two at Tarapur (commissioned in 1977 and 2011) and one at Kalpakkam (commissioned in 1998), each with a design capacity of 100 tons of spent fuel per year. A second 100 tons per year plant is under construction at Kalpakkam and is expected to start operations in 2014.[105] The plants together are estimated to have separated about 4.7 tons of plutonium from power reactor fuel as of the end of 2012.[106] There are an additional 0.24 tons of plutonium under safeguards.

India is constructing a 500 MWe Prototype Fast Breeder Reactor (PFBR) that will be fueled with a mixture of plutonium and uranium oxide. The PFBR has an initial inventory of 1.9 tons of plutonium in its core.[107] Construction of the PFBR began in 2004, but it has experienced a series of delays; it is now expected to go critical in September 2014 and begin commercial operation a year later, according to the chairman of BHAVINI, the Indian government agency responsible for building the reactor.[108] The PFBR's estimated costs have gone up from the initial Rs.35 billion to nearly Rs.57 billion (i.e., from about $700 million to about $1.1 billion).[109]

***Japan.*** Japan's Rokkasho reprocessing plant faced further delays in 2012.[110] It is not expected to begin operation until after Japan's Nuclear Regulation Authority has approved new safety standards, which it is expected to do in December 2013.[111] The plant is now over 15 years behind schedule; it was originally planned to start up in 1997.

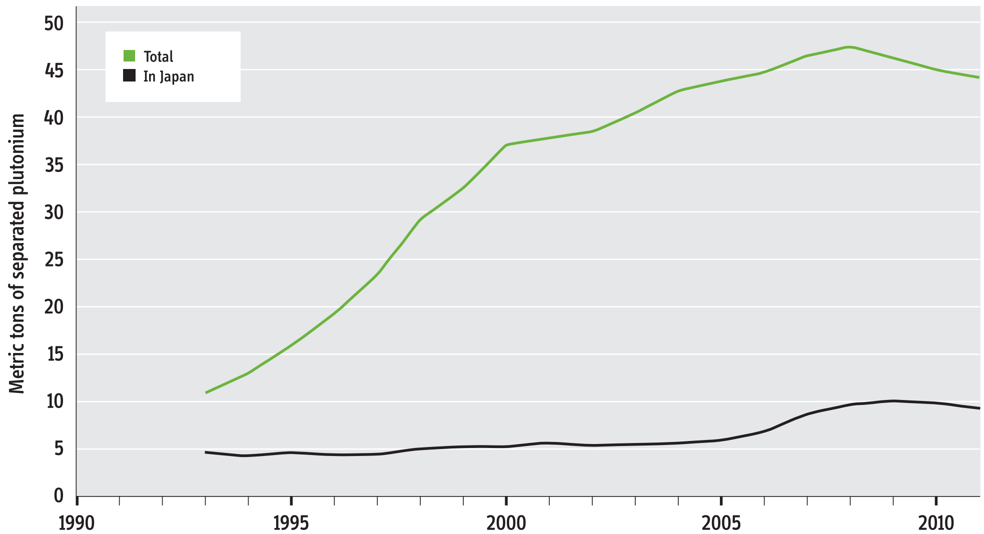


**Figure 1.7. Japan's plutonium stockpile has grown over the past two decades despite the problems with its Rokkasho reprocessing plant.** As of 1993, Japan had a stockpile of about 5 tons of separated plutonium at the Tokai reprocessing plant, which operated from 1981 to 2006, but was shut down from 1997 to 2002 because of an accident. It had about the same amount in France and the United Kingdom. Separation of Japan's plutonium in France was completed in 1999 and in the United Kingdom in 2005. The amount of plutonium stored abroad has declined as some has been returned to Japan as MOX fuel. The increase in the stockpile after 2006 was a result of hot-testing at the Rokkasho reprocessing plant.

It remains uncertain when or if Rokkasho may start full commercial operation. In December 2012, earthquake faults were discovered that may run under the Rokkasho site, located in Aomori prefecture, raising concerns about the safety of the facility.[112]

Safety concerns have also led Japan's Nuclear Regulation Authority to indefinitely suspend the restart of the Monju prototype fast breeder reactor after the operator, the Japan Atomic Energy Agency, was discovered to not have inspected properly nearly 10,000 pieces of equipment, including those used in the safety and emergency systems, for several years.[113] The Monju reactor went critical in 1994, but operation was halted in 1995 after a sodium leak that shut it down until May 2010. The attempt to restart operation was halted after three months, following an accident, and the reactor has not operated since. There is now concern that an earthquake fault may run under the reactor.[114]

# Appendix 1.1 Uranium Enrichment Plants

| Facility | Type | Operational Status | Safeguards Status | Capacity [tSWU/yr] |
|---|---|---|---|---|
| **Argentina** | | | | |
| Pilcaniyeu | Civilian | uncertain | yes | TBD |
| **Brazil** | | | | |
| Resende | Civilian | Being commissioned | yes | 115–200 |
| **China** | | | | |
| Shaanxi | Civilian | Operating | (yes) | 1000 |
| Lanzhou II | Civilian | Operating | offered | 500 |
| Lanzhou (new) | Civilian | Operating | no | 1000 |
| **France** | | | | |
| George Besse II | Civilian | Operating | yes | 7500–11000 |
| **Germany** | | | | |
| Gronau | Civilian | Operating | yes | 2200–4500 |
| **India** | | | | |
| Ratehalli | Military | Operating | no | 15–30 |
| **Iran** | | | | |
| Natanz | Civilian | Under construction | yes | 120 |
| Qom | Civilian | Under construction | yes | 5–10 |
| **Japan** | | | | |
| Rokkasho | Civilian | Resuming Operation | yes | 50-1500 |
| **Netherlands** | | | | |
| Almelo | Civilian | Operating | yes | 5000-6200 |
| **North Korea** | | | | |
| Yongbyon | ? | ? | no | (8) |
| **Pakistan** | | | | |
| Kahuta | Military | Operating | no | 15–45 |
| Gadwal | Military | Operating | no | Unknown |
| **Russia** | | | | |
| Angarsk | Civilian | Operating | offered | 2200–5000 |
| Novouralsk | Civilian | Operating | no | 13300 |
| Zelenogorsk | Civilian | Operating | no | 7900 |
| Seversk | Civilian | Operating | no | 3800 |
| **United Kingdom** | | | | |
| Capenhurst | Civilian | Operating | yes | 5000 |
| **United States** | | | | |
| Paducah, Kentucky | Civilian | Shutdown in 2013 | offered | 11300 |
| Piketon, Ohio | Civilian | Planned | offered | 3800 |
| Eunice, NM | Civilian | Operating | offered | 5900 |
| Areva Eagle Rock, Idaho | Civilian | Planned | (offered) | 3300–6600 |
| GLE, Wilmington, NC | Civilian | Planned | ? | 3500–6000 |

Where a range of capacities is shown, the facility is expanding its capacity—except for Pakistan, where the range denotes uncertainty in estimated capacity.

# Appendix 1.2 Reprocessing Plants

| Facility | Type | Operational Status | Safeguards Status | Capacity (tHM/yr) |
|---|---|---|---|---|
| **China** | | | | |
| Pilot Plant | Civilian | Operating | (no) | 50–100 |
| **France** | | | | |
| UP2 | Civilian | Operating | yes | 1000 |
| UP3 | Civilian | Operating | yes | 1000 |
| **India** | | | | |
| Trombay | Military | Operating | no | 50 |
| Tarapur-I | Dual | Operating | no | 100 |
| ADD Tarapur-II | Dual | Operating | no | 100 |
| Kalpakkam | Dual | Operating | no | 100 |
| **Israel** | | | | |
| Dimona | Military | Operating | no | 40–100 |
| **Japan** | | | | |
| Rokkasho | Civilian | Starting up | yes | 800 |
| Tokai | Civilian | Temporarily shut down | yes | 200 |
| **North Korea** | | | | |
| Yongbyon | Military | On standby | no | 100–150 |
| **Pakistan** | | | | |
| Nilore | Military | Operating | no | 20–40 |
| Chashma | Military | Under construction | no | 50–100 |
| **Russia** | | | | |
| RT-1 | Dual | Operating | no | 200–400 |
| Seversk | Dual | Shutdown | no | 6000 |
| Zheleznogorsk | Dual | Shutdown | no | 3500 |
| **United Kingdom** | | | | |
| B205 | Civilian | To be shutdown after cleanup | yes | 1500 |
| THORP | Civilian | Scheduled for Shutdown | yes | 1200 |
| **United States** | | | | |
| H-canyon, SRP | Converted | Special Operations | no | 15 |

# Appendix 1.3 Civilian Plutonium Stockpile Declarations

| | France (Addendum 5) | | Japan (Addendum 1) | | Russia (Addendum 9) | | United Kingdom (Addendum 8) | | United States (Addendum 6) | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1996 | 65.4 | 30.0 | 5.0 | 0.0 | 28.2 | 0.0 | 54.8 | 6.1 | 45.0 | 0.0 |
| | | 0.2 | | 15.1 | | 0.0 | | 0.9 | | 0.0 |
| 1997 | 72.3 | 33.6 | 5.0 | 0.0 | 29.2 | 0.0 | 60.1 | 6.1 | 45.0 | 0.0 |
| | | <0.05 | | 19.1 | | 0.0 | | 0.9 | | 0.0 |
| 1998 | 75.9 | 35.6 | 4.9 | 0.0 | 30.3 | 0.0 | 69.1 | 10.2 | 45.0 | 0.0 |
| | | <0.05 | | 24.4 | | 0.0 | | 0.9 | | 0.0 |
| 1999 | 81.2 | 37.7 | 5.2 | 0.0 | 32.0 | 0.0 | 72.5 | 11.8 | 45.0 | 0.0 |
| | | <0.05 | | 27.6 | | 0.0 | | 0.9 | | 0.0 |
| 2000 | 82.7 | 38.5 | 5.3 | 0.0 | 33.4 | 0.0 | 78.1 | 16.6 | 45.0 | 0.0 |
| | | <0.05 | | 32.1 | | 0.0 | | 0.9 | | 0.0 |
| 2001 | 80.5 | 33.5 | 5.6 | 0.0 | 35.2 | 0.0 | 82.4 | 17.1 | 45.0 | 0.0 |
| | | <0.05 | | 32.4 | | 0.0 | | 0.9 | | 0.0 |
| 2002 | 79.9 | 32.0 | 5.3 | 0.0 | 37.2 | 0.0 | 90.8 | 20.9 | 45.0 | 0.0 |
| | | <0.05 | | 33.3 | | 0.0 | | 0.9 | | 0.0 |
| 2003 | 78.6 | 30.5 | 5.4 | 0.0 | 38.2 | 0.0 | 96.2 | 22.5 | 45.0 | 0.0 |
| | | <0.05 | | 35.2 | | 0.0 | | 0.9 | | 0.0 |
| 2004 | 78.5 | 29.7 | 5.6 | 0.0 | 39.7 | 0.0 | 102.6 | 25.9 | 44.9 | 0.0 |
| | | <0.05 | | 37.1 | | 0.0 | | 0.9 | | 0.1 |
| 2005 | 81.2 | 30.3 | 5.9 | 0.0 | 41.2 | 0.0 | 104.9 | 26.5 | 45.0 | 0.0 |
| | | <0.05 | | 37.9 | | 0.0 | | 0.9 | | 0.0 |
| 2006 | 82.1 | 29.7 | 6.7 | 0.0 | 42.4 | 0.0 | 106.9 | 26.5 | 44.9 | 0.0 |
| | | <0.05 | | 38.0 | | 0.0 | | 0.9 | | 0.0 |
| 2007 | 82.2 | 27.3 | 8.7 | 0.0 | 44.9 | 0.0 | 108.0 | 26.8 | 53.9 | 0.0 |
| | | <0.05 | | 37.9 | | 0.0 | | 0.9 | | 0.0 |
| 2008 | 83.8 | 28.3 | 9.6 | 0.0 | 46.5 | 0.0 | 109.1 | 27.0 | 53.9 | 0.0 |
| | | <0.05 | | 37.8 | | 0.0 | | 0.9 | | 0.0 |
| 2009 | 81.8 | 25.9 | 10.0 | 0.0 | 47.7 | 0.0 | 112.1 | 27.7 | 53.9 | 0.0 |
| | | <0.05 | | 36.15 | | 0.0 | | 0.9 | | 0.0 |
| 2010 | 80.2 | 24.2 | 9.9 | 0.0 | 48.4 | 0.0 | 114.8 | 28.0 | 53.9 | 0.0 |
| | | <0.05 | | 35.0 | | 0.0 | | 0.9 | | 0.0 |
| 2011 | 80.3 | 22.8 | 9.3 | 0.0 | 49.5 | 0.0 | 118.2 | 27.9 | 49.3 | 0.0 |
| | | <0.05 | | 35.0 | | 0.0 | | 0.9 | | 0.0 |
| 2012 | 80.6 | 22.2 | 9.3 | 0.0 | | | 120.2 | 23.8 | | |
| | | <0.05 | | 34.9 | | | | 0.9 | | |

Inventory held in country (white) — Foreign-owned (included in local inventory) (light green)

Stored outside the country (not included in local inventory) (green)

The annual inventories (as of December 31st of the respective year) listed in the table are in tons. The declarations give the fissile material stocks at reprocessing plants, fuel-fabrication plants, reactors, and elsewhere, divided into non-irradiated forms and irradiated fuel. Russia does not include in its declaration excess weapons plutonium, whereas the United States and UK do.

# 2 Increasing Transparency of Nuclear Warheads and Fissile Material Stocks and Production Histories

The "Action Plan on Nuclear Disarmament" agreed at the 2010 Nuclear Non-Proliferation Treaty (NPT) Review Conference affirmed "the need for the Nuclear weapon states to reduce and eliminate all types of their nuclear weapons."[115] It also was agreed that "nuclear disarmament and achieving the peace and security of a world without nuclear weapons will require openness and cooperation, and … enhanced confidence through increased transparency and effective verification."[116]

Under the terms of the Action Plan, the NPT nuclear weapon states agreed further to cooperate with each other and with the broader international community on steps to foster confidence, increase transparency and develop verification capabilities related to nuclear disarmament; to report information that can further openness and verification; and to provide regular reports on progress on such steps.[117] The nuclear weapon states are expected to report to the NPT Preparatory Committee in 2014 on their progress, with the 2015 Review Conference charged to "take stock and consider the next steps" towards nuclear disarmament.[118]

NPT non-weapon states and the larger international community have encouraged and supported increased transparency by the weapon states. In some cases, non-weapon states have made specific proposals for transparency measures that could contribute to the disarmament process. For example, at the 2008 NPT Preparatory Committee, Japan suggested categories of information that weapon states might disclose as part of increased transparency measures.[119] At the 2010 Review Conference, Australia and New Zealand also proposed reporting categories.[120]

Since then, the 10-country Non-Proliferation and Disarmament Initiative (NPDI) has sought to "promote transparency in nuclear disarmament reporting," and to develop "a draft standard nuclear disarmament reporting form."[121] In April 2012, NPDI presented a model reporting form that weapon states could consider.[122] The United Nations Office for Disarmament Affairs in 2011 established on its official web site a page for the eventual establishment of a "Repository of information provided by nuclear weapon states."[123]

The five NPT weapon states—China, France, Russia, the United Kingdom and the United States—have met in London (September 2009), in Paris (June–July 2011) and Washington DC (June 2012) to discuss “issues of transparency and mutual confidence, including nuclear doctrine and capabilities, and of verification.”[124] In their June 2012 meeting, they “continued their previous discussions on the issues of transparency, mutual confidence, and verification, and considered proposals for a standard reporting form.”[125]

At present, not all the NPT nuclear weapon states can be expected to be equally forthcoming or able to become more transparent at the same rate. All could agree, however, on first steps that could be part of their report to the Preparatory Committee in 2014. This would allow their initial declarations to be considered by the 2015 NPT Review Conference and decisions to be made about future transparency steps. Declarations by some weapon states that go beyond the minimal first steps suggested here would help demonstrate to the others that even greater openness is possible and that the costs of such transparency are acceptable.

Even without immediate verification, an initial set of consistent baseline declarations covering warhead and fissile material inventories would strengthen confidence in the weapon states’ commitment to openness and to a verifiable disarmament process. Such declarations, supplemented by warhead and fissile material production and disposition histories, could provide the essential background information required for the negotiation and verification of deep reductions in nuclear arsenals and eventual elimination of nuclear weapons.

For non-nuclear weapon states party to the NPT, all items containing fissile materials must be declared by location to the International Atomic Energy Agency (IAEA), although the information is considered “safeguards-confidential” and therefore not made public. These declarations are subject to IAEA verification—including by counting and measurements on random samples of the declared items. In meeting their disarmament commitments, the NPT weapon states eventually also may have to agree to provide the equivalent of the “initial report on all nuclear material which is to be subject to safeguards” required from non-weapon state parties to the NPT.[126] This will require “a national system of accounting for and control of nuclear materials,” like those required in the non-weapon states that cover historical production, utilization and losses in waste.[127] If they have not done so already, weapon states should organize such accounts—and the records and physical data behind them—while they are still available.

Finally, while directed at the NPT nuclear weapon states, the proposals offered here could be adopted by nuclear weapon states that are not party to the NPT as part of their contributions to reaching the agreed goal of nuclear disarmament.[128]

## Baseline declarations that could be made by 2015

In the 2010 NPT “Action Plan,” the NPT nuclear weapon states committed “to undertake further efforts to reduce and ultimately eliminate all types of nuclear weapons, deployed and non-deployed.”[129] The Action Plan also noted the “increased transparency of some nuclear weapon states with respect to the number of nuclear weapons in their national inventories” and encouraged “all nuclear weapon states to provide additional transparency in this regard.”[130]

Some of the NPT nuclear weapon states have released information about the sizes, makeups, and histories of their nuclear warhead stockpiles, but with widely varying degrees of detail and timeliness. This information has been released unilaterally in public statements or as part of bilateral agreements (such as U.S.-Russian strategic arms limitation agreements). This information has allowed independent analysts to estimate weapon-state warhead and fissile-material stocks and how they have changed over time.[131]

To make their declarations comparable and consistent over time, the weapon states should develop agreed terminology defining nuclear warheads and warhead components, and their deployment, storage, and stages of dismantlement.[132] The United States and Russia have reached agreement on an extensive glossary of terms as part of their bilateral arms control treaties that may offer a starting point, although some of the definitions suitable for U.S.-Russian purposes—for example, what constitutes a "strategic delivery vehicle"—may have to be amended when other nuclear weapon states are included.

For instance, under the terms of the 2010 U.S.-Russian New START agreement, three categories of strategic delivery system are defined and limits on their deployment established: land-based intercontinental ballistic missiles (ICBMs), submarine-launched ballistic missiles (SLBMs), and heavy bombers.[133] The agreement defines an ICBM as a ballistic missile with a demonstrated range of more than 5500 km. For an SLBM to be covered by New START, it has to have a demonstrated range of more than 600 km. A heavy bomber is defined as either a bomber with a range of more than 8000 km or a bomber that can carry long-range nuclear air-launched cruise missiles (which are defined as cruise missiles with a range of more than 600 km). In order to be counted against the New START limit of 700 deployed delivery systems, a ballistic missile must be installed in a launcher: a silo, a road-mobile launcher, or a launch tube on a submarine. All heavy bombers that fit the definition and are located at declared air bases are also counted as deployed unless they are converted to non-nuclear missions according to a procedure described in the treaty.

With or without agreement on terminology, the nuclear weapon states could begin to make baseline declarations of their stocks of nuclear warheads and fissile materials.

#### Warhead stocks

First steps towards greater transparency that could be adopted by the NPT weapon states in advance of the 2015 NPT Review Conference are:

- Baseline declarations of the total numbers of nuclear warheads in their possession as of a specific recent date with a commitment to subsequent annual updates.

For weapon states willing to do so, these initial declarations could be disaggregated to include numbers of:

- Operational nuclear warheads, deployed warheads (and associated delivery vehicles), and retired warheads awaiting dismantlement; and

- Separated warhead components in storage (fissile-material in the form of "pits" from fission "primaries" and fission-fusion "secondaries").

Disaggregated declarations of the numbers of warheads and components, as of a specified date and annual updates (for a possible reporting form, see Table 2.1) would provide an initial snapshot of the state of the arsenal of each NPT weapon state.

| Inventory | |
|---|---|
| **Total number of warheads as of (DATE)** | ............ |
| Operationally deployed warheads (strategic) | ............ |
| Operationally deployed warheads (tactical) | ............ |
| Warheads in active reserve | ............ |
| Warheads in inactive reserve (no tritium) | ............ |
| Retired warheads in dismantlement queue | ............ |
| Warhead components in storage, primaries | ............ |
| Warhead components in storage, secondaries | ............ |

**Table 2.1. A possible reporting form for nuclear warheads by deployment status.** This information could be refined further by warhead type/designation. In the absence of an agreed definition, each NPT weapon state would provide its own list of which delivery vehicles it considered "strategic" and which it considered "tactical." Most NPT weapon states have already made public some data relating to their nuclear arsenals. These are discussed in Chapter 4.

#### Potential New START-type declarations by all NPT weapon states

The New START treaty between the United States and Russia that came into force in February 2011 set a new standard of bilateral transparency that has potential applicability to future nuclear arms reduction treaties involving other nuclear weapon states as well.[134] The key advantage of New START and its predecessor, the Strategic Arms Reduction Treaty (START), which was in force from 1994 to 2009, is that they provide a legal and organizational framework for strategic nuclear reductions that has been thoroughly tested in practice. The information exchange provisions in New START were framed to facilitate effective verification but, even prior to actual verification, extending the framework to all nuclear weapon states would be a natural and direct way of building confidence that a comprehensive system to ensure transparency and accountability in nuclear disarmament could eventually be achieved.

By requiring its parties to account for operationally deployed strategic delivery systems and warheads, New START makes it possible to closely track progress toward nuclear force reductions. Also, by limiting the number of launchers, the treaty sets an upper bound on the number of strategic nuclear warheads that could be deployed.

Participation in a New START-type transparency regime could be accomplished through a series of voluntary initiatives by individual nuclear weapon states, done either in coordination or unilaterally. During this process, each state would decide on the classes of information it would be willing to release, the amount of information that would be openly available, and the verification activities that it would be willing to join in. Unlike Russia and the United States, other nuclear weapon states do not have to assume legal obligations regarding specific limits on nuclear arsenals. But they could use the framework of the treaty to demonstrate progress in the "systematic and progressive efforts to reduce nuclear weapons" to which they committed themselves at the 1995 NPT Review and Extension Conference.[135]

As the first step toward transparency of their nuclear arsenals, the other nuclear weapon states could join Russia and the United States in disclosing the following aggregate numbers for their strategic nuclear forces in the form defined in New START, including:

- The numbers of deployed strategic delivery systems (ICBMs, SLBMs, and bombers)

- The number of deployed strategic warheads, and

- The number of deployed and non-deployed strategic launchers (silos, road-mobile launchers, missile launch tubes on submarines).

Disclosure of these numbers would provide a basic level of transparency of the strategic nuclear arsenals.

### Fissile material stocks

Efforts to increase nuclear transparency, including through regular reporting, have so far focused primarily on the size and makeup of nuclear arsenals. Transparency measures could, however, also usefully include declarations about nuclear weapon-state fissile material stocks, production and stockpile histories. Since fissile materials are the key ingredients of nuclear weapons, these declarations complement those concerning the weapons themselves, offering an additional basis for confidence in and support for future nuclear weapon reduction efforts. Declarations of fissile material stocks are especially significant since all five NPT nuclear weapon states have ended the production of fissile materials for weapon purposes.

As part of their baseline declarations, by 2015, NPT nuclear weapon states could make public their:

- Total holdings of plutonium and of highly enriched uranium (HEU) as of a specific recent date.

The United States has made detailed declarations for both its HEU and plutonium stockpiles as of 1996 and 1994 respectively and provided subsequent updates.[136] These U.S. declarations included the amounts of HEU and plutonium that were received from or transferred to other countries, although the amount of HEU transferred to the United Kingdom under a military cooperation agreement was kept secret. The United Kingdom, in 1998, declared its total fissile material stocks.[137] China, France and Russia have not made public any information on their total fissile material stocks. Independent, albeit uncertain, estimates of fissile material stocks exist for all the weapon states.[138]

Since 1997, all the NPT weapon states have made annual declarations of their civilian plutonium stocks to the IAEA, which, by agreement, publishes them on its website.[139] (Along with the NPT weapon states, Belgium, Germany, Switzerland, and Japan also have made such INFCIRC/549 declarations.) China made its first non-zero declaration in 2011. The United Kingdom and France (and Germany) also declare stocks of civilian HEU in their INFCIRC/549 declarations.

To avoid ambiguities and to allow for consistency checks, the baseline national declarations of fissile materials should list separately:

- HEU and plutonium in other countries and any foreign-owned material in country.

In these initial declarations, weapon states also could declare:

- The portions of their HEU and plutonium stockpiles available for IAEA safeguards.

Material in this last category could be civilian or excess military material. Some of this material may already be under international safeguards, be eligible for safeguards, or have been declared as civilian to the IAEA. Civilian fissile materials in France and the United Kingdom, for example, are under Euratom safeguards and the United States declares its excess military plutonium annually as civilian to the IAEA in its INFCIRC/549 declarations. The NPT weapon states could break down the total quantities of HEU and plutonium as shown in Table 2.2.

| | HEU | Plutonium |
|---|---|---|
| **Inventory as of (DATE)** | | |
| Military, available for weapons | | |
| Military, reserved for non-weapon purposes | | |
| Military, in irradiated fuel | | |
| Excess military, not available for IAEA safeguards | | |
| Civilian, not available for IAEA safeguards | | |
| Civilian, available for IAEA safeguards | | |
| Excess military, available for IAEA safeguards | | |

**Table 2.2. A possible reporting form for a fissile-material declaration that disaggregates the baseline categories for fissile materials.** Material available for weapons includes material for or in warheads that are deployed, in reserve, awaiting dismantlement, and in components. In addition, average isotopics (uranium-235 content in HEU and plutonium-239 content in plutonium) could be specified. This would allow for further consistency checks of the declarations.

Non-NPT weapon states could consider making baseline declarations that only list fissile material stocks available and not available for safeguards, since such declarations would not reveal information on actual nuclear warhead numbers.

**IAEA monitoring and irreversibility**

Action 16 of the 2010 NPT Review Conference Final Document states:

> “The nuclear weapon states are encouraged to commit to declare, as appropriate, to the International Atomic Energy Agency (IAEA) all fissile material designated by each of them as not required for military purposes and to place such material as soon as practi-

> cable under IAEA or other relevant international verification and arrangements for the disposition of such material for peaceful purposes, to ensure that such material remains permanently outside military programmes."

To meet this commitment, each NPT weapon state could declare and place under IAEA safeguards:

- All plutonium and HEU in civilian use.
- All plutonium and HEU recovered from excess weapons or its nuclear-weapons complex and declared excess for weapon purposes.
- All plutonium and HEU going to waste disposal sites.

Russia and the United States are disposing of significant quantities of excess weapons HEU and plutonium. Russia is expected to complete in 2013 the blend-down of 500 tons of excess weapon-grade HEU into low-enriched uranium (LEU) that is being sold to the United States for use in power reactor fuel. This blend-down is being monitored on a bilateral basis. The United States has similarly blended down about 141 tons of excess HEU, some of it under IAEA monitoring.[140]

Russia and the United States agreed to conclude IAEA verification arrangements for their agreement on disposal of 34 tons each of plutonium declared excess for weapons purposes.[141] None of this excess plutonium has yet been disposed of. As of the middle of 2013, agreement on verification had not been reached.

The United Kingdom has been dismantling warheads withdrawn from service but in 2013 the government told Parliament that "the material from dismantled warheads is returned to the MOD [Ministry of Defence] nuclear material stockpile. It is not government policy to place this material under international safeguards."[142]

In principle, the IAEA could monitor containers holding fissile materials declared excess while they were still in the form of nuclear warhead components, whose contained fissile material mass, isotopic composition and other details may be classified. That each container did indeed contain at least a threshold quantity of weapon-grade fissile material could be verified using radiation measurements and information barrier techniques such as those developed for plutonium-containing warhead "pits" as part of the Trilateral Initiative between the IAEA, the United States, and Russia during 1996–2002.[143]

Action 16 does not commit weapon states to declare and place under IAEA safeguards HEU allocated for military naval fuel. Nuclear weapon states could in principle still do so, however, and use the provision of the NPT that allows any state, even non-weapon states, to withdraw fissile material from safeguards for use in military but non-weapons activities.[144]

This use of fissile material is significant because the quantities of HEU reserved for naval reactor fuel are huge. The United States alone has set aside for naval fuel a stockpile of 152 tons of weapon-grade uranium—enough for more than 6000 nuclear weapons.[145] In addition to the United States, the United Kingdom, and Russia operate HEU-fueled naval reactors. France and (we believe) China do not use HEU in their naval fuel.[146]

In the United States, as of the end of 2009, about 4.8 tons of plutonium had been sent to the Waste Isolation Pilot Plant (WIPP) in New Mexico for geological disposal.[147] To establish confidence in declarations of fissile material going to waste, weapon states should agree to declare the amount of fissile material in each waste package, and allow the IAEA to do independent assays on random waste drums containing significant amounts of fissile material and monitor the perimeter of the waste facility.

Expanding IAEA safeguards into the nuclear weapon states will require supplementing the IAEA safeguards budget.

## Preparations for future declarations to support deep reductions agreements

Irreversible reductions to low numbers of warheads and much smaller stockpiles of fissile material for military purposes will require still greater transparency for effective verification. The NPT weapon states therefore should acknowledge the future need to provide public information on the production histories and planned developments in their warhead and fissile material stockpiles. They also should commit at the 2015 Review Conference to begin to prepare such information for later disclosure in the context of deep-cuts agreements.

### Warhead and delivery system locations

The next step toward greater openness of strategic nuclear forces would involve publication of detailed reports similar to those that Russia and the United States exchange every six months as part of the New START agreement. These biannual reports include information on:

- The locations of deployed delivery vehicles and the number of deployed warheads at each operational base;

- The assignment of a unique identification number to each missile, aircraft, and missile launcher, whether deployed or not.

Disclosure of this information would represent a significant advance in transparency of nuclear forces for all states involved in the process, since today no country publicly releases information about strategic nuclear arsenals with the amount of detail specified in New START. The treaty, of course, requires Russia and the United States to submit this information to each other, but it allows them to withhold it from the public. Russia has chosen not to release any part of its New START reports. The United States makes public an unclassified version that withholds some of the data.

The assignment of unique identification numbers is an especially important precedent that could pave the way toward a verification system in which every nuclear warhead would be given a unique identification number, a procedure that would be valuable and possibly indispensable as countries moved toward nuclear disarmament.

### Warhead stockpile histories

In the case of warheads, information to be prepared for future declarations should include:

- Total nuclear-warhead stockpiles by year and numbers of warheads built, retired, and dismantled each year.

The United States has already made public information on total and dismantled nuclear weapons.[148] In 2013, the United Kingdom revealed that some warheads withdrawn from service as part of planned reductions are being dismantled, but it has not revealed the total number of warheads that have been dismantled or the average annual rate of dismantlement.[149] France has indicated that significant numbers of warheads formerly in its arsenal are no longer operational—but has not revealed whether these warheads have been dismantled or not.

States that are concerned about revealing too much information about their current nuclear stockpiles could begin by revealing the data for warhead-types that no longer exist.[150]

The nuclear weapon states also could increase confidence and transparency by declaring their:

- Plans for future warhead production, life-extension, deployment, and disassembly for the next five years.[151]

The five-year plans—which could be timed to match the five year NPT Review Conference cycle—could be updated each year to indicate progress in meeting them. They also could include schedules for production, life-extensions and dismantlement of delivery systems.

#### Fissile material production and disposal histories

Four of the five NPT nuclear weapon states have announced that they have ended plutonium production for weapons and HEU production for all military purposes. The fifth, China, is believed to have halted production for more than two decades.[152] It is in this context that Action 18 of the 2010 NPT Review Conference Final Document states,

> "All States that have not yet done so are encouraged to initiate a process towards the dismantling or conversion for peaceful uses of facilities for the production of fissile material for use in nuclear warheads or other nuclear explosive devices."

- As a first step, weapon states could declare all shutdown fissile material production facilities, the state of shutdown, and their decommissioning or conversion plans.

- As a second step, weapon states could release detailed data on HEU and plutonium production and related waste production and disposal records.

It is relevant to note that, in May 2008, to back up its declaration of its plutonium stockpile, North Korea provided about 18,000 pages of records on the operations of its plutonium production reactor and the associated reprocessing facility between 1986 and that date.[153]

### Cooperative verification projects

As part of their meetings in 2009 and 2011, the NPT nuclear weapon states have "shared information on their respective bilateral and multilateral experiences in verification."[154] By the 2015 NPT Review Conference, the weapon states could agree to pursue new bilateral, trilateral, and multilateral cooperative projects with IAEA participation to develop and demonstrate verification approaches for both warhead dismantlement and declarations of past fissile-material production.

### Cooperative verification patterned after New START

The NPT nuclear weapon states already participate in a range of verification and inspection activities related to arms control and disarmament treaties, such as the Chemical Weapons Convention, the treaty on Conventional Forces in Europe, the Open Skies treaty, and bilateral agreements. Even though only Russia and the United States are currently conducting inspections at strategic nuclear force facilities, all nuclear weapon states have the organizational structure that could support verification and inspection activities of the New START type.

New START includes very detailed verification procedures that are designed to ensure accuracy of the information on strategic forces supplied by the parties. These procedures include a ban on interference with national technical means of verification, exhibits of delivery systems, exchange of telemetry information, and detailed provisions for on-site inspections. Extending these verification activities to all nuclear weapon states would be an important trust and confidence building measure that would create institutional arrangements to support the nuclear disarmament process.

The inspections could be conducted on a voluntary and reciprocal basis at the initiative of individual countries. In most cases, actual on-site inspection activities would require a formal agreement between the governments that would regulate access of foreign inspectors to the facilities, non-disclosure of information obtained during inspections, and other legal issues. Based on experience with other arms control agreements, however, there is no reason to believe that these issues could not be resolved on a bilateral or multilateral basis. To facilitate this process, Russia and the United States could invite other states to conduct demonstration inspections at their facilities in order to share their experience of carrying out inspections activity.

### Warhead dismantlement

The main rationale behind verifying warhead dismantlement is to provide confidence that actual warheads have been destroyed and that the fissile material they contained has been recovered and accounted for. In general, the dismantlement process can be divided in several stages, each posing different verification challenges:

1. Monitoring the chain of custody of warheads from deployment or storage to the dismantlement facility using tags and seals on their containers;

2. Verification that the warheads going into a dismantlement facility have indeed been dismantled and application of tags and seals to the containers of plutonium and HEU-containing components coming out;

3. Verified dismantlement of the plutonium and HEU components; and

4. Monitored disposition of recovered HEU and plutonium.

In the 1990s, U.S. and Russian weapon laboratories cooperated in developing chain-of-custody arrangements to allow Russian inspectors to verify U.S. warhead dismantlement.[155] The United Kingdom and Norway have conducted a five-year-long exercise on nonintrusive verification of nuclear warhead dismantlement involving a dummy warhead, and have been sharing what they learned with both weapon and non-weapon states.[156] Both these efforts could be resumed and extended to include all the NPT weapon states, the IAEA, and some non-weapon states.

During 1996–2002, the United States, Russia, and the IAEA also engaged in a Trilateral Initiative to develop tools and procedures to enable the non-intrusive monitoring of plutonium-containing weapon components in storage. This effort could be resumed and expanded to include the other nuclear weapon states and to cover weapon components containing HEU.

As noted earlier, Russia and the United States have been carrying out programs to dispose of HEU declared excess to military purposes. As part of this effort, the parties established transparency measures to provide the U.S. assurance that Russian LEU was derived from weapon-grade metal and Russia confidence that the LEU is used for fuel.[157] Work is still underway with the IAEA on the verification arrangements for the disposal of excess weapon-grade plutonium. Both efforts could be expanded to include other nuclear weapon states.

**Past fissile material production**

Verifying declarations of past fissile material production would require access to former fissile material production sites. Once nuclear weapon states release information on the production histories of materials by site and facility, they could also agree on the terms of access to these sites by foreign partners or multilateral or international teams with IAEA participation to carry out measurements to make consistency checks on declarations of quantities and types of fissile materials produced there.

Since most of the facilities used for fissile material production for weapons are now shut down and many are scheduled for decommissioning, to allow for future verification, weapon states should as soon as possible:

- Catalogue and preserve operating records and waste materials.

States also could pursue new cooperative projects to develop the methods of "nuclear archaeology," which uses nuclear-forensic analysis of samples from structural or waste materials to obtain evidence relating to the operating history of nuclear production facilities. In the 1990s, the United States, with some cooperation from the United Kingdom, France, and Russia, started to develop and demonstrate nuclear archaeology methods for graphite-moderated production reactors.[158]

New nuclear archaeology projects are needed, however, to deal with other kinds of facilities used for fissile material production and to recover useful forensic information from wastes associated with fissile material production. These projects could consider verification opportunities associated with:

- Dedicated plutonium production reactors (graphite and heavy-water moderated);

- High-level waste from military reprocessing;

- Gaseous diffusion, electromagnetic, and centrifuge uranium enrichment facilities that were used for HEU production; and

- Depleted uranium stored at enrichment facilities.

As an example, Table 2.3 lists the main plutonium (and tritium) production reactors in NPT nuclear weapon states. None of these facilities remains operational. Some are now open to visitors. The U.S. Hanford B reactor, for example, has been declared a National Historic Landmark and opened for public tours.[159] In 2009, France invited observers to visit its enrichment and plutonium production complexes at Pierrelatte and Marcoule, undergoing dismantlement.[160] China has revealed an unfinished underground plutonium production complex ("Project 816") at Fuling in Sichuan Province and opened it up for tourists.[161]

| | Graphite Reactors | Heavy Water Reactors |
|---|---|---|
| United States | Hanford: 9 reactors (B, D, F, H, DR, C, KW, KE, N) | Savannah River: 5 reactors (R, P, K, L, C) |
| Russia | Mayak: 5 reactors (A, AV-1, -2, -3, AI-IR)<br>Seversk: 5 reactors (I-1, IE-2, ADE-3, -4, -5)<br>Zheleznogorsk: 3 reactors (AD, ADE-1, -2) | Mayak: 4 reactors<br>(OK-180, -190, -190M, LF-2) |
| United Kingdom | Sellafield: 6 reactors (Windscale, Calder Hall)<br>Chapelcross: 4 reactors | n/a |
| France | Marcoule: 3 reactors (G1, G2, G3) | Marcoule: 2 Célestin reactors |
| China | Jiuquan: 1 reactor<br>Guangyuan: 1 reactor | n/a |

**Table 2.3. Main plutonium (and tritium) production reactors in NPT nuclear weapon states.** All these plants are now shut down and in various stages of decommissioning.

Many former military fissile material production facilities have been shut down for decades and are in various stages of decommissioning. So far, however, these facilities have not been used for nuclear archaeology projects. Weapon states could choose a former production reactor or enrichment plant for projects to develop and test verification approaches. "Partner sites" could be offered to jointly demonstrate these methods. By limiting such activities initially to single facilities at selected sites, weapon states would not reveal information about their total past fissile material production before they are ready to do so. Priority should be given to transparency projects at facilities scheduled for decommissioning and waste materials that are scheduled for further processing or elimination.

# 3 Nuclear Weapon State Transparency, the Nuclear Non-Proliferation Treaty and the United Nations

The United Nations—encompassing its Secretariat and its Member States—has been working on the elimination of nuclear weapons since the adoption of the General Assembly's first resolution on 24 January 1946. Yet 66 years later, not only has nuclear disarmament not been achieved, there are still not even official figures of the precise number of nuclear weapons and delivery systems in the world—nor the quantities of nuclear-weapon-usable fissile materials. It has been left to independent analysts to estimate the number of nuclear weapons and the quantities of fissile materials.[162] In this effort, fact-finders are confronted with unilateral declarations, "ceilings," and opacity.

The responsibility for this at-best uneven rate of progress in disarmament is primarily born by the nuclear weapon states, which bear ultimate responsibility for making decisions on the status of their nuclear arsenals and their associated fissile materials. There is a particular responsibility borne by China, France, Russian Federation, United Kingdom and United States, the five permanent members of the UN Security Council and the only nuclear weapon states of the Nuclear Non-Proliferation Treaty (NPT).

For its part, the UN serves as a unique global forum for the deliberation, promulgation, adaptation, and enforcement of multilateral norms intended to apply universally. In the field of disarmament, various components of what is known as the "UN disarmament machinery"—including the UN Disarmament Commission, the General Assembly's First Committee, and the Conference on Disarmament—along with other multilateral arenas (including those associated with the Comprehensive Nuclear-Test-Ban Treaty and NPT) have cumulatively produced a short list of standards denoting what qualifies as a "good" disarmament agreement. Evidence for these standards appears in General Assembly resolutions, Final Documents of NPT Review Conferences, and other products of multilateral arenas commanding a consensus or near-consensus.

**Figure 3.1. The first meeting of the United Nations General Assembly, London, January 1946.** Passed on 24 January 1946, General Resolution 1.1 established a commission to draw up a plan "for the elimination from national armaments of atomic weapons." *Source: United Nations Photo.*

The standards intended for use in assessing progress made by the nuclear weapon states in fulfilling their disarmament commitments can be reduced to five key metrics:

- transparency
- verification
- irreversibility
- universality
- abidingness

The fulfillment of these five multilateral standards would address many of the criticisms to the goal of pursuing a world without nuclear weapons. Reduced to their essentials, twelve such criticisms are repeated endlessly in disarmament critiques, which insist that disarmament is: utopian; impractical; dangerous; unverifiable; unenforceable; etc.[163] A fundamental purpose of "transparency" in disarmament is to address one of the most challenging criticisms of nuclear disarmament—namely, that there just never seems to be a sufficient level of "trust" or "confidence" to permit serious progress toward zero.

Confidence-building could be called the raison d'être of transparency. When the information derived from transparency arrangements is verified, confidence is enhanced all the more. When it is augmented by specific controls to eliminate the risk of reversibility of disarmament commitments, it is strengthened even further. And when such arrangements are implemented universally pursuant to binding legal obligations, they become indisputable as a foundation for security and order in a world without nuclear weapons.

Given transparency is so important, where do the United Nations, the NPT States Parties, and in particular the five nuclear weapon state parties of the NPT, stand today on efforts to improve it?

## The United Nations and the NPT Review Process

Transparency has been growing in importance as part of the NPT review process and as an issue for the United Nations. Step 9 of the famous "thirteen steps" on nuclear disarmament that were agreed by consensus in the 2000 NPT Review Conference, called for "increased transparency by the nuclear weapon states with regard to the nuclear weapons capabilities and the implementation of agreements pursuant to article VI and as a voluntary confidence-building measure to support further progress on nuclear disarmament."[164]

Similarly, to track progress in implementing nuclear disarmament commitments under the treaty, step number 12 provided for:

> "Regular reports, within the framework of the strengthened review process for the Non- Proliferation Treaty, by all States parties on the implementation of article VI and paragraph 4 (c) of the 1995 Decision on "Principles and Objectives for Nuclear Non-Proliferation and Disarmament", and recalling the advisory opinion of the International Court of Justice of 8 July 1996."[165]

There was little progress, however. On 24 October 2008, the Secretary-General announced a five-point nuclear disarmament proposal—his fourth point specifically addressed the need for greater transparency:

> "The nuclear weapon states often circulate descriptions of what they are doing to pursue these goals, yet these accounts seldom reach the public. I invite the nuclear weapon states to send such material to the United Nations Secretariat, and to encourage its wider dissemination. The nuclear Powers could also expand the amount of information they publish about the size of their arsenals, stocks of fissile material and specific disarmament achievements. The lack of an authoritative estimate of the total number of nuclear weapons testifies to the need for greater transparency."[166]

Speaking in October 2009 as the UN's High Representative for Disarmament Affairs, Sergio Duarte linked transparency in an NPT context directly to the goals of the treaty:

> "Transparency is not a dispensable option for ensuring accountability under the treaty, both with respect to non-proliferation and disarmament commitments, as well as to peaceful uses. If there is little or no transparency, how are the States parties supposed to assess progress in achieving the goals of the treaty, especially with respect to disarmament? Basic facts about weapon production, stockpiles, and holdings of fissile material are absolutely essential in the establishment of a "base line" from which to assess progress in disarmament. Without such facts, how is the whole "confidence-building" function of transparency to be achieved? If states are to rely exclusively upon discretionary reporting on progress in disarmament, on what grounds can a stricter standard be applied to assess compliance in non-proliferation? Any treaty that applies a full-transparency standard for most of its parties—without corresponding requirements for some of them—will inevitably encounter difficulties.[167]

Six months later, the States Parties to the NPT concluded their 2010 Review Conference, whose Final Document consisted of two parts: a summary report section written by the President of the Review Conference on his own authority, and a 64-point "Action Plan" for future progress in strengthening the three pillars of the treaty: disarmament, non-proliferation, and peaceful uses.[168] The report section stressed the importance of bilateral and regional safeguards in promoting transparency and mutual confidence between states (Paragraph 26), the need for transparency in export controls (Paragraph 26), and the need for "additional transparency" in the nuclear-weapon inventories of the nuclear weapon states (Paragraph 94).


**Figure 3.2. The 2010 NPT Review Conference, New York.** The conference set out an "Action Plan on Nuclear Disarmament" that included a range of obligations for the nuclear weapon states. As parties to the NPT, the United States, United Kingdom, Russia, France and China are covered by these obligations. North Korea was a party to the treaty but withdrew in 2003. Israel, India and Pakistan are not signatories to the NPT. *Source: United Nations Photo.*

The rest of the Final Document referred to consensus language on the "Action Plan." Action 2 stated, "All States parties commit to apply the principles of irreversibility, verifiability and transparency in relation to the implementation of their treaty obligations." Action 5, which addressed specific actions by the nuclear weapon states, included subparagraph (g), which read, "Further enhance transparency and increase mutual confidence…". Subparagraph (i) affirmed "the importance of enhanced confidence through increased transparency and effective verification."

Action 19 recognized a role for civil society:

> All States agree on the importance of supporting cooperation among Governments, the United Nations, other international and regional organizations and civil society aimed at increasing confidence, improving transparency and developing efficient verification capabilities related to nuclear disarmament.

Action 20 states that States parties should submit "regular reports" on the implementation of this Action Plan, and Action 21 went further, stating:

> As a confidence-building measure, all the nuclear weapon states are encouraged to agree as soon as possible on a standard reporting form and to determine appropriate reporting intervals for the purpose of voluntarily providing standard information without prejudice to national security. The Secretary-General of the United Nations is invited to establish a publicly accessible repository, which shall include the information provided by the nuclear weapon states.

In 2011, the UN Secretariat's Office for Disarmament Affairs established a page on its official web site relating to Action 21 of the 2010 NPT Review Conference.[169] The page is essentially a "place-keeper" for the eventual establishment of a "Repository of information provided by nuclear weapon states." The future of this transparency instrument —whose lineage can be traced back to decades of efforts to improve transparency of nuclear weapons disarmament progress at the United Nations (discussed below)—is entirely dependent upon the readiness of the states possessing nuclear weapons to contribute the relevant data.

The determination of what types of data should be contributed is still up to the nuclear weapon states, though the Secretary-General's 24 October 2008 speech did suggest the following types of information: "the size of their arsenals, stocks of fissile material and specific disarmament achievements." This would logically include "base-line" declarations on: bombs and warheads (both deployed and non-deployed), weapon-usable fissile material in both military and civilian programs, facilities for the production of both nuclear weapons and their fissile materials, and delivery systems for "strategic" weapons (land-based missiles, bombers, air-launched missiles, and submarine-launched missiles), including both cruise and ballistic missiles, as well as tactical or so-called non-strategic weapons.[170] The level of detail of these declarations would certainly grow the closer the arsenals approached zero, as would the level of verification and controls for irreversibility.

Following the 2010 NPT Review Conference, the States Parties met in 2012 for the first session of the Preparatory Committee for the 2015 NPT Review Conference. Two coalitions of States Parties presented "working papers" specifically addressing transparency. The ten members of the Non-Proliferation and Disarmament Initiative (discussed later) focused on item 21 of the Action Plan; they proposed a "standard reporting form" to enhance transparency.[171] This form would require reporting on the number, types and status of nuclear warheads; the number and if possible types of delivery vehicles; the number and types of weapons and delivery systems dismantled and reduced; the amount of fissile material produced for military purposes; and measures taken "to diminish the role and significance of" nuclear weapons. The proposal indicated that these data should be reported in the NPT review process.

The second group of states was the New Agenda Coalition, consisting of Brazil, Egypt, Ireland, Mexico, New Zealand, South Africa, and Sweden.[172] While this paper focused mostly on verification, it also indicated that the nuclear weapon states should:

> commit themselves to annually submitting accurate, complete and comprehensive reports on their nuclear arsenals, weapons-grade highly enriched uranium and plutonium stockpiles and

> production histories, in addition to material irreversibly removed from nuclear weapons programmes, in conformity with all articles of the Treaty, especially articles I and II.[173]

A lengthy (28-paragraph) joint statement by the nuclear weapon states at the 2012 Preparatory Committee session only briefly touched upon transparency, saying that "we continued our previous discussions" and "considered proposals for a standard reporting form."[174]

## Approaches to transparency in the UN disarmament machinery

Since its reorganization following the General Assembly's first Special Session on disarmament in 1978, the UN Disarmament Commission has not adopted any guidelines or recommendations specifically on transparency issues with respect to nuclear weapons.

By contrast, the First Committee of the General Assembly has addressed nuclear weapons transparency fairly regularly, if somewhat tangentially.[175] In recent years, three nuclear weapons resolutions have briefly addressed this issue—the resolutions in 2011 were:

- Resolution 66/40, introduced by New Zealand (on behalf of the seven-member New Agenda Coalition); and recalled the commitment of the nuclear weapon states at the 2010 NPT Review Conference "to further enhance transparency and mutual confidence";

- Resolution 66/45, introduced by Japan; emphasized "the principles of irreversibility, verifiability, and transparency" in nuclear disarmament and non-proliferation; affirmed "the importance of enhanced confidence through increased transparency and effective verification"; and welcomed the Paris meeting of the P5 in June 2011 as a "transparency and confidence-building measure among them"; and

- Resolution 66/51, introduced by Myanmar (with the co-sponsorship of several members of the Non-Aligned Movement); and underlined "the importance of applying the principles of transparency, irreversibility, and verifiability" in nuclear disarmament.

In 2011, there was an additional resolution introduced by Iran to "follow-up" on the nuclear disarmament obligations agreed at the 1995, 2000, and 2010 NPT Review Conferences. Adopted by a vote of 118-52-6 (yes-no-abstain), Resolution 66/28 called (inter alia) for "increased transparency" on the part of the nuclear weapon states in implementing agreements pursuant to NPT Article VI.

The Conference on Disarmament in Geneva has been unable to commence negotiations on any new multilateral disarmament treaties since concluding its work on the Comprehensive Nuclear-Test-Ban Treaty in 1996. Its efforts to start work on a fissile material treaty (what many call a "cut-off" treaty)—which certainly would have implications for nuclear transparency—have failed to achieve a consensus.

In December 2012, the General Assembly adopted Resolution 67/53, which requested the Secretary-General to establish a 25-member group of governmental experts to meet in Geneva for two 2-week sessions in 2014 and 2015.[176] The group is mandated "to make recommendations on possible aspects that could contribute to but not negotiate" a treaty banning the production of fissile material for nuclear weapons. The resolution also indicated that the group should conclude its work if the Conference on Disarmament was able to adopt a balanced and comprehensive program of work. In short, the General Assembly clarified its intent that the Conference should be the negotiating forum for that treaty.

## Steps taken by the nuclear weapon states

The response of the NPT nuclear weapon states (some of them at least) to growing demands for transparency has come in two forms: unilateral declarations, typically in the form of ceilings on deployed strategic warheads, and consultations amongst these states in a collective effort to respond to these calls for greater transparency. Of the five NPT nuclear weapon states, only China has demurred on providing information on its arsenal, fissile material and delivery systems, while the other four have at least declared ceilings of their deployed nuclear warheads and/or some details on current and historical production of fissile material and stocks. There is little to no transparency of the nuclear-weapon stocks of the non-NPT states (India, Israel, Pakistan and North Korea).

The nuclear weapon states have started a process to work out a common response to the growing demands for transparency. These are described by the participants as meetings of the permanent members of the UN Security Council (the P5). The first of the recent P5 meetings was entitled "confidence building measures towards disarmament and non-proliferation issues" and that meeting pre-dated the 2010 NPT Review Conference. It was held in London on 3–4 September 2009.[177] A brief press release was issued, which contained few details of the discussions—these meetings are held in private—while acknowledging that one of the issues discussed included "building mutual confidence through voluntary transparency and other measures." A prominent theme of this conference was the consideration of the various "conditions to enable further progress" in implementing Article VI (disarmament) of the NPT.

Following the May 2010 NPT Review Conference, France hosted the next P5 meeting on 30 June and 1 July 2011 in Paris.[178] The purpose of that meeting was "to consider progress on the commitments they made" at the Review Conference; their Joint Statement referred specifically to commitments made pursuant to Action 5 "as well as reporting." They recognized "the issues of transparency and mutual confidence" as "important for establishing a firm foundation" for further progress in disarmament. They established a working group to consider the development of an agreed glossary of key nuclear terms. Other subjects addressed included verification, NPT withdrawal, the CTBT, efforts to conclude a fissile material "cut-off" treaty, a Middle East WMD Free Zone, and safeguards issues. Elaborating the language of NPT Article VI, they also called on all states—including non-NPT states—to "contribute to" nuclear disarmament. (At their first Summit meeting on nuclear disarmament and non-proliferation on 24 September 2009, the Security Council adopted Resolution 1887, which also contained this call for universal action on nuclear disarmament beyond Article VI of the NPT.[179])

**Figure 3.3. United Nations Security Council, New York, September 2009.** A special heads of state summit session of the Security Council, chaired by President Barack Obama, approved Resolution 1887 "to seek a safer world for all and to create the conditions for a world without nuclear weapons." *Source: United Nations Photo.*

On 27–29 June 2012, the third such P5 meeting took place in Washington, DC. Their joint statement issued afterward referred briefly to transparency but essentially repeated language adopted at the second meeting on continuing their discussions and considering proposals on a standard reporting form.[180] The United States announced that a fourth P5 conference would occur "in the context of the next NPT Preparatory Committee in 2013."[181]

It is not clear if, when, or in what format or scope the P5 will agree to contribute data to the "repository" that the UN Secretariat has established upon the request of the 2010 NPT Review Conference. As of mid-2013, the UNODA repository remains empty. The 2010 Final Document "called upon" the P5 states to report on their undertakings on Action 5 (which included transparency) at the third session of the Preparatory Committee in 2014, on the eve of the Review Conference the following year. Regardless of the venue for reporting these data, the international support for increased transparency will certainly persist.

## Steps taken by non-weapon states

Over the years, several coalitions of states have advanced various nuclear weapons transparency initiatives linked to the NPT framework.

As noted earlier, the seven-country New Agenda Coalition has for many years introduced General Assembly resolutions on nuclear disarmament issues; this coalition had a significant impact in shaping the 13 steps for nuclear disarmament agreed at the 2000 NPT Review Conference. The Non-Aligned Movement, which has 120 member states, circulated a Working Paper at the 2010 NPT Review Conference that outlined a three-stage proposal for achieving nuclear disarmament. The proposal included the following pertaining to transparency, to be achieved in the 2010–2015 period: "Clear and verifiable declarations by States of their stocks of nuclear weapons and nuclear-weapons-usable material and agreement on a multilateral mechanism to monitor reductions by nuclear weapon states of their nuclear arsenals individually, bilaterally or collectively."[182]

After the 2010 Review Conference, ten foreign ministers met in New York in September that year to form a group "to take forward the consensus" reached at that NPT event. Later called the "Non-Proliferation and Disarmament Initiative" (NPDI), the group adopted a Joint Statement at their September 2010 meeting to urge the nuclear weapon states (inter alia) "to pursue confidence building measures such as effective verification and increased transparency, including by reporting regularly on progress in implementing their disarmament undertakings."[183] The Joint Statement also indicated that the countries will consider "how we might most effectively contribute to the development of the 'standard reporting form' for use by the nuclear weapon states" in meeting their disarmament commitments made at the 2010 Review Conference.

The countries met again in Berlin in April 2011 and issued the "Berlin Statement" that indicated that they were developing a draft standard reporting form as a means to inform the nuclear weapon states of "our expectations regarding information that we would like to see all states possessing nuclear weapons provide."[184] In September 2011, meeting again in New York, the 10 ministers issued another joint statement, which reported that the members of the group "have now shared our proposed reporting form with the P5."[185]

In June 2012, the NPDI issued a joint statement from Istanbul saying "We call upon all nuclear weapon states to intensify efforts to reduce and eventually eliminate all types of nuclear weapons, deployed and non-deployed, in a transparent, verifiable and irreversible manner." The statement also took note of the P5 meetings and commented (somewhat ironically) "We urge transparency in their work."[186]

## Transparency initiatives outside the United Nations

The number of transparency initiatives originating outside the UN and NPT framework are too numerous to address comprehensively here. The following are identified solely to demonstrate their variety and longevity. The list includes both official actions and non-governmental proposals.

There are various bilateral agreements between the Russian Federation and the United States which provide inter alia for the exchange of information on deployed strategic nuclear forces (e.g. the New Start treaty) and certain fissile materials (e.g. the 1993 Highly Enriched Uranium agreement and the 2000 Plutonium Management and Disposition Agreement). Especially noteworthy was the Joint Statement by Presidents Yeltsin and Clinton in 1997 on parameters for further reductions in nuclear forces. Included in that statement was a commitment to begin negotiations on a follow-up treaty to START II (which never entered into force), that would include:

> Measures relating to the transparency of strategic nuclear warhead inventories and the destruction of strategic nuclear warheads and any other jointly agreed technical and organizational measures, to promote the irreversibility of deep reductions including prevention of a rapid increase in the number of warheads.[187]

More recently, the April 2010 Second Conference of States Parties and Signatories of Treaties that Establish Nuclear-Weapon-Free Zones and Mongolia concluded by adopting an Outcome Document stressing that "all nuclear disarmament initiatives should be irreversible, transparent and verifiable."[188] At that time, there were 115 states parties and signatories to nuclear weapon free zone treaties.[189]

The "Nuclear Security Summit" held in April 2010 in Washington, DC, and in March 2012 in Seoul provided some additional opportunities to strengthen transparency, at least with respect to certain fissile materials.[190] The primary themes of these events related to nuclear non-proliferation, nuclear terrorism, and physical security of nuclear material—with disarmament and fissile materials in military stocks not being central themes. The final communiqués, however, did not mention transparency.[191]

Several independent international commissions that have included former policy makers have stressed the importance of improvements in transparency, including: the Canberra Commission,[192] the Tokyo Forum,[193] the WMD Commission,[194] and the International Commission on Nuclear Non-Proliferation and Disarmament.[195] The Asia Pacific Leadership Network for Nuclear Non-Proliferation and Disarmament, which consists of thirty former political, diplomatic and military leaders from thirteen countries around the region, has also addressed transparency. This group has urged the nuclear weapon states "to set an example by undertaking national audits of their historical production of fissile material, as a basis for later discussions amongst them, and in due course with other nuclear-armed states, on problems encountered and how they might be addressed."[196]

Finally, various private research groups and NGOs have addressed transparency issues at length in recent studies on achieving nuclear disarmament, including the Carnegie Endowment for International Peace,[197] the Stimson Center,[198] and many others. The Frankfurt Peace Research Institute has issued several reports on nuclear weapons transparency issues, including a specific proposal for a nuclear-weapons register.[199] A group of NGOs has drafted a Model Nuclear Weapons Convention that includes the following language on transparency: "To participate in good faith in activities aimed at the promotion of transparency with respect to nuclear weapons and related technologies …";[200] two versions (1997 and 2007) have been circulated at the UN as official UN documents.[201] Useful work on improving NPT reporting has also been undertaken by Canadian NGOs, including the Canadian Network to Abolish Nuclear Weapons[202] and Project Ploughshares.[203]

It is certain that at some point in the global nuclear disarmament process, the quality of transparency especially over all fissile material—both military and civilian—will be critical to the future success of that process. As Secretary-General Ban Ki-moon once put it, "We should never forget that the nuclear fuel cycle is more than an issue involving energy or non-proliferation; its fate will also shape prospects for disarmament."[204]

## Conclusion

While necessarily incomplete, this survey provides the basis for seven substantive conclusions:

1. Efforts to improve transparency of nuclear arsenals and progress in achieving nuclear disarmament enjoy widespread support in the world community, including but not exclusively at the United Nations, and this support has endured for decades.

2. Some progress in improving transparency has occurred, but almost entirely through unilateral, unverified declarations, and without universal support or participation by all states that possess such weapons.

3. Future efforts to strengthen transparency will likely involve a combination of additional unilateral declarations coupled with possible new agreements among nuclear-weapon possessors, depending upon the outcome of future P5 deliberations.

4. Most transparency proposals appear to be based on common sense reasoning, logical deduction, and conformity to some ideal type or model (stated or unstated), rather than close examination of the practical political realities of achieving full implementation. It is one thing to identify what a good agreement should ideally contain, another to offer a political plan of action to get it implemented; such a plan would have to consider actions by coalitions of non-nuclear weapon states, leadership from within the nuclear weapon states, and advocacy by civil society.

5. A leading multilateral forum for advocacy of collective efforts to improve transparency in the years ahead will be the NPT review process, based on the expectations created by the 2000 and 2010 Review Conferences, especially vis-à-vis reporting. This judgment will depend to a significant extent on whether the review process is successful in increasing transparency over the remaining nuclear arsenals, the relevant fissile materials, and concrete steps to implement disarmament commitments.

6. Finally, the NPT cannot be the exclusive forum for progress on transparency, if the other multilateral disarmament goal of "universality" is ever to be achieved—at some point, the non-NPT states must make their own contributions to transparency. While it will be entirely up to those states to decide what and when to divulge, those decisions have at least the potential to be influenced, perhaps significantly, by on-going progress in nuclear disarmament elsewhere, diplomatic initiatives by coalitions of countries, and sustained pressure from civil society.

7. There is no need to establish a central United Nations repository of information relevant to nuclear disarmament. It already exists: the challenge now is to fill it.

# 4 Nuclear Warhead Stockpiles and Transparency

Historically there have been few things more secret than the details about nuclear weapons. In recent years, though, certain facts have become known about the number of nuclear weapons and the quantities of fissile material that have been produced in certain countries. This chapter reviews the recent transparency record about nuclear warhead stockpiles, deployment status, production, and dismantlement.

## United States

Compared with other nuclear weapon states, the United States has, despite its own degree of secrecy, disclosed a considerable amount of information about the status and history of its nuclear weapons arsenal.

On May 3, 2010, the Department of Defense released a fact sheet showing the number of warheads in the stockpile from 1962 to 2009.[205] The release followed the declassification in 1994 by Secretary of Energy Hazel O'Leary of the figures from 1945 to 1961.[206] Thus, there is now a complete official public history of the rise and decline of the U.S. stockpile from 1945 through September 30, 2009.

The stockpile has continued to decline slightly since 2009 due to retirement of the W62 warhead previously deployed on the ICBM force, and excess W76 and B83 warheads. It is estimated that the stockpile currently stands at approximately 4650 warheads. It includes seven basic warhead types: B61, W76, W78, W80, B83, W87, and W88.[207] Recent reductions include roughly 260 warheads from the retirement of the nuclear Tomahawk sea-launched cruise missile (TLAM/N).

Since 2010, the government has not released specific information about the size of the stockpile or number of dismantlements. National Security Advisor Thomas Donilon declared in March 2011 that the size of the stockpile "stands at approximately 5000 warheads, including both deployed and reserve warheads."[208] In November 2011, James Miller, the Principal Deputy Under Secretary of Defense for Policy, stated that the 5113 number "has dropped slightly" since then.[209] The 2010 disclosure was a "one-time release," according to one U.S. official, and in response to a Freedom of Information Act request from the Federation of American Scientists in 2013 for the current size of the nuclear stockpile, the Department of Defense responded that denied information was classified.[210]

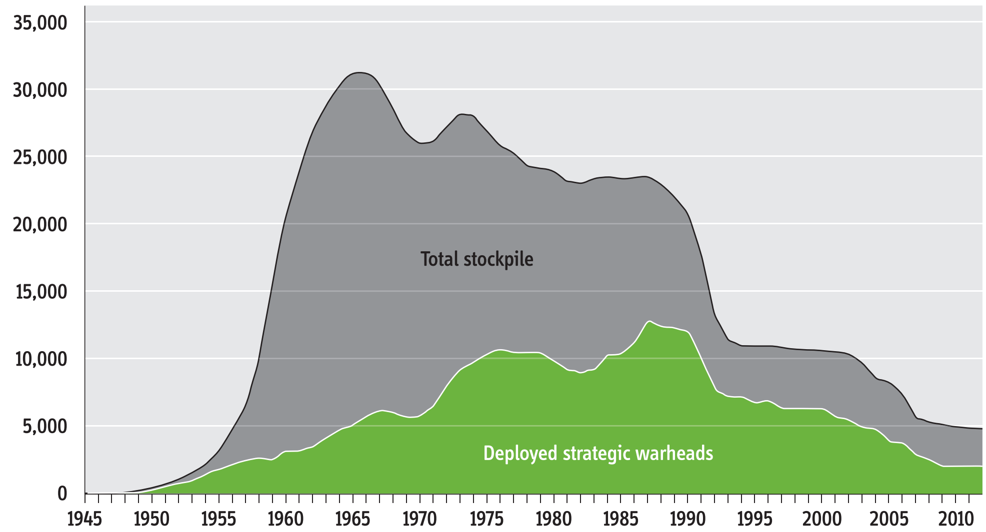


**Figure 4.1. The United States nuclear stockpile and deployed strategic warheads 1945–2012.** The size of the US stockpile peaked in 1967 and been declining almost continuously since 1973. The number of deployed strategic warheads peaked in 1987. The stockpile now stands at approximately 4650 warheads with roughly 3000 retired—but still intact—warheads awaiting dismantlement (authors' estimates).

The aggregate data released under the New START treaty attributes 1654 warheads to deployed delivery vehicles as of March 1, 2013.[211] Weapons are not fully counted for bombers, which are attributed one weapon each. But since the treaty counts actual numbers of warheads on ballistic missiles and the number of bombers was disclosed (111), the actual number of warheads deployed on ballistic missiles was 1545. Downloading of the remaining Minuteman ICBMs to single warhead is underway, and the government plans to reduce by 2018 the number of accountable deployed strategic warheads to no more than 1550 and the number of deployed strategic delivery vehicles to no more than 240 SLBMs, 420 ICBMs, and 60 nuclear-capable bombers to meet the New START Treaty limit of no more than a total of 700 deployed strategic delivery vehicles. As many as 100 additional non-deployed strategic delivery vehicles are permitted by the treaty.

Non-strategic warhead numbers have not been declassified but the government has provided percentage reductions. The April 2010 stockpile declassification also included a statement that the "number of U.S. non-strategic nuclear weapons declined by approximately 90 percent from September 30, 1991 to September 30, 2009."[212] This reduction from roughly 7600 to 760 non-strategic warheads has been most dramatic in Europe, where the stockpile was reduced by approximately 95 percent since 1991. With the retirement of the TLAM/N, the reduction since 1991 is at 93 percent.

Also significant has been the elimination of all non-strategic naval nuclear weapons, the last of which (the nuclear Tomahawk SLCM) was announced in the 2010 Nuclear Posture Review. Overall, the trend is that the United States unilaterally is eliminating all non-strategic nuclear weapons. The final phase will be the consolidation of four non-strategic and one strategic versions of the B61 bomb into one type (B61-12) in 2019–2022 as part of the B61 life-extension program. When completed, the United

States will no longer have designated non-strategic nuclear warheads in its stockpile; whether a weapon is non-strategic or strategic will depend on the delivery platform rather than the warhead (the B61-12 will be carried on the B2-A bomber, F-35, F-16, and F-15E fighters).

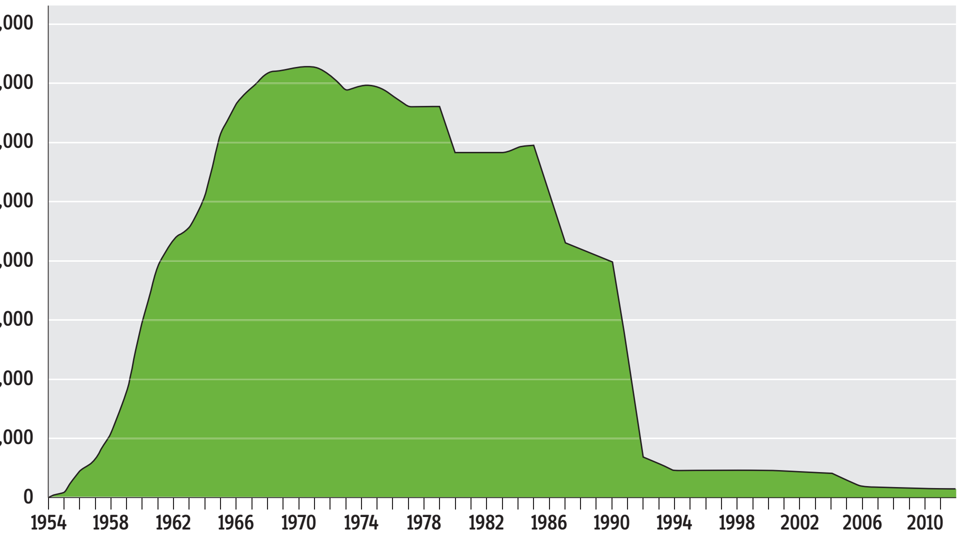


**Figure 4.2. U.S. non-strategic nuclear weapons in Europe 1945–2012.** The number of US non-strategic nuclear weapons in Europe peaked at roughly 7300 warheads in 1971 and has pretty much declined ever since. All the cuts have been unilateral, the most significant taking place in 1991–1993, however, in the context of reciprocal unilateral cuts by the Soviet Union, and a less well-known 50 percent reduction in 2005–2006 (authors' estimates).

The government disclosures also included information about dismantlements of nuclear weapons, but these numbers are less complete. The 1994 disclosure listed "disassemblies" from 1980 through April 1994, a term that normally includes disassembly for inspection as well as disassembly for dismantlement. In contrast, the 2010 disclosure explicitly listed "dismantlements" for the years 1994 through 2009. The government says "several thousand" retired warheads are awaiting dismantlement but does not disclose the specific number. It is estimated that the dismantlement queue currently includes about 3000 warheads. The dismantlement of warheads retired up through 2009 is scheduled for completion in 2022.[213]

Annual dismantlement rates currently fluctuate around 300–400 warheads, compared with more than 1000 during the 1990s. The number is largely set by the Pantex disassembly and reassembly of life-extension and surveillance warheads. The low dismantlement rate means that it can take many years between the time when warheads are retired and their eventual dismantlement: The W79 warhead for the 8-inch Howitzer artillery shell was retired in 1993 and dismantlement completed in 2003; the W70 warhead from the Lance short-range missile was retired in 1993 and dismantlement completed in 2011; the B53 strategic bomb was retired in 1997 and dismantlement completed in 2011. The dismantlement queue still includes W69 (Poseidon) and W71 (Spartan) warheads that were retired in 1993 and 1975, respectively.

Initiatives to increase transparency of the U.S. stockpile should include annual declarations of its size, the number and types of warheads dismantled, and the number of warheads awaiting dismantlement. The number of non-strategic nuclear weapons should also be disclosed, as should the number of these weapons deployed in Europe. Some locations could also be disclosed, beginning with the locations where nuclear weapons have been removed. Histories for the weapons no longer in the stockpile also should be declassified.

## United Kingdom

The British government declared in May 2010, following the U.S. declassification of its stockpile, that, "in [the] future, our overall stockpile will not exceed 225 nuclear warheads."[214] The previous government had declared in 2006 that, "fewer than 160" warheads would be "operationally available."[215] The balance of approximately 65 warheads, the government said, was "to allow for routine processing, maintenance, and logistic management."[216]

The disclosure of the stockpile size followed several statements, beginning with the Strategic Defence Review in 1998 that included a chart that listed the relative number of stockpile warheads in the 1970s, 1980s, early-1990s and 1998. While no specific stockpile numbers were provided, the document declared that a single ballistic missile submarine on patrol would carry 48 warheads. The Strategic Defence Review also declared that the last tactical nuclear weapon, the WE-177, was withdrawn in March 1998.[217]

The October 2010 Strategic Defence and Security Review subsequently announced plans to shrink the stockpile and number of deployed warheads even further. It declared the number of operationally available warheads will be reduced "from fewer than 160 to no more than 120," and the number of warheads on each deployed submarine will drop from 48 to 40. This reduced requirement will, in turn, permit a reduction of the overall stockpile "from not more than 225 to not more than 180 by the mid-2020s."[218]

The Strategic Defence and Security Review also declared that the number of operational SLBMs on each Vanguard-class ballistic missile submarine will be reduced "over the next few years" to "no more than eight." Moreover, the next generation of submarines will be "configured with only eight operational missile tubes, rather than the 16 on the current Vanguard class."[219]

Coinciding with these government statements, important documents have been declassified and made available in the British National Archives that trace the history of the United Kingdom nuclear stockpile up until the late-1970s.[220] It is still not clear what the peak was, but it appears to have around 500, although government statements indicate that it might have been higher.[221]

Steps to increase the transparency of the British nuclear stockpile should include disclosure of year-by-year data for total number of warheads and dismantlements. Histories for the weapons no longer in the stockpile and dismantlements also should be declassified.

## France

In March 2008, French president Nicolas Sarkozy declared with regard to the airborne portion of the French arsenal, "the number of weapons, missiles and aircraft will be reduced by one-third." After that reduction, he stated, "our arsenal will include fewer than 300 nuclear warheads. That is half of the maximum number of warheads we had during the Cold War." Sarkozy said that in giving this information, "France was completely transparent because it has no other weapons besides those in its operational stockpile."[222]

The last part of the declaration was probably intended to signal that France, unlike the United States, does not maintain a large reserve of non-deployed nuclear warheads. Like other nuclear weapon states, however, France likely has a small inventory of spare warheads. Moreover, at the time of the declaration, France was producing or had finished producing new TNA (Tête Nucleaire Aéroportée) warheads for the ASMP-A air-launched cruise missile that first entered the arsenal in 2009. Likewise, the new TNO (Tête Nucléaire Océanique) warhead that is scheduled to begin replacing the existing TN75 warhead on the M51 SLBM from 2015 might have been in production when Sarkozy gave his speech. It seems likely, therefore, that additional warheads existed at the time. It is estimated that about 290 warheads are deployed with more in stock as spares and new production warheads.[223]

France could increase transparency by specifying the history and numbers of warheads in its operational and total stockpiles. Moreover, it should also disclose the histories of warhead types that are no longer in the stockpile, and it should disclose the history of its warhead dismantlements.

## Russia

After the dissolution of the Soviet Union, for a short time there were occasional official statements that helped anchor estimates of the size of the Soviet/Russian stockpile and the sizes of the various steps to reduce it. The statements varied, however, leaving considerable uncertainty about the size and composition of the stockpile. Over the past decade, Russian officials have not provided information about the size of the Russian arsenal other than numbers for counted strategic warheads under arms control treaties.

In February 1992, the Washington Post quoted the Russian Minister of Atomic Energy (Minatom), Victor Mikhailov, as saying that a common estimate used at the time for the Soviet arsenal containing some 27,000 warheads was "the lowest estimate." He said the estimate was accurate "within 15 to 20 percent," which the Washington Post interpreted could mean the arsenal was "as high as 32,000 warheads."[224] Eighteen months later, Mikhailov stated that Russia had over 40,000 nuclear weapons at the beginning of 1986, and that the number had since been reduced by "virtually 15,000" weapons,[225] suggesting an arsenal of more than 25,000 nuclear weapons.

These estimates largely correspond to estimates published by the U.S. intelligence agencies at the time. In late 1991, as the Soviet Union was beginning to break up, the CIA stated that the Soviet arsenal included some 30,000 nuclear weapons.[226] After the Soviet breakup, the CIA stated, in May 1992, that it estimated that Russia possessed 30,000 nuclear weapons, with an uncertainty of about 5000 warheads.[227]

Since then, perhaps 20,000 Russian warheads have been dismantled. The U.S. Defense Department in November 2011 cited "unclassified estimates" saying "Russia has 4000 to 6500 total nuclear weapons,"[228] indicating that classified estimates might be similar. The number is associated with considerable uncertainty because of the large number of nuclear weapons in storage (strategic and non-strategic) and uncertainty about which portion of them is a reserve or awaiting dismantlement.

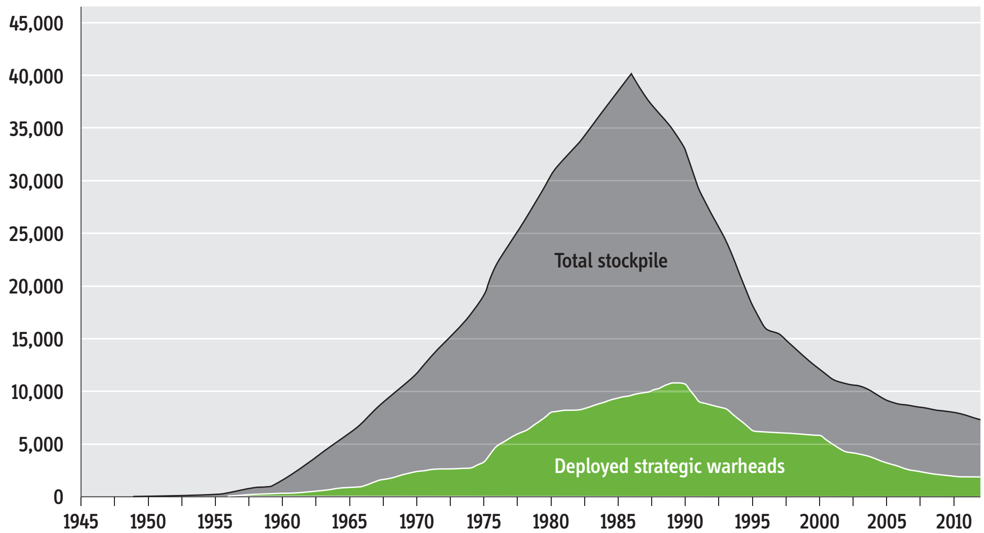


**Figure 4.3. Russian nuclear stockpile and deployed strategic warheads 1945-2012.** The size and history of the Russian nuclear stockpile is associated with considerable uncertainty. The stockpile appears to have peaked in 1986, and the number of deployed strategic warheads in 1989. The stockpile now stands at approximately 4500 warheads but thousands of retired—but still intact—warheads are awaiting dismantlement (authors' estimates).

During the old START treaty, detailed aggregate numbers for Russian strategic nuclear forces were released by the U.S. State Department. During the negotiations of the New START Treaty, however, Russia insisted on making it illegal for the State Department to release the detailed aggregate numbers. As a consequence, no official detailed overview of Russian strategic nuclear forces has been available to the public since July 2009, resulting in increased public uncertainty about the Russian arsenal.[229] The New START Treaty aggregate data attributes 1480 deployed strategic warheads to Russian forces as of March 1, 2013.[230] With an estimated 60 or so deployed bombers (each attributed one weapon), the actual number of accountable deployed strategic warheads on ballistic missiles is approximately 1420.

The number of Russian non-strategic nuclear weapons is also associated with considerable uncertainty. Estimates of the number as of the end of the Cold War range from 13,000 to 21,700. The Russian government stated in 2005 (and again in 2010) that its non-strategic weapons had been reduced by four times since 1991.[231] If so, the inventory would have declined to 3200–5400 warheads by 2005. Retirement has probably continued and the U.S. Defense Department in November 2011 referred to an "unclassified estimate" suggesting that Russia had 2000–4000 non-strategic weapons.[232] Based on a count of delivery platforms for non-strategic weapons and nominal warhead loadings, Russian non-strategic nuclear forces are assigned approximately 2000 warheads.[233] The Russian government states that "all Russian non-strategic nuclear weapons are concentrated in centralized storage bases exclusively ob [sic] the national territory."[234] Some storage sites are near operational bases.

To increase nuclear transparency and avoid creating uncertainty and worst-case assumptions in NATO countries and China, Russia should disclose the history and size of its total nuclear arsenal, and the history and status of warhead dismantlement. Locations of deployed strategic warheads are largely known, but Russia could also disclose locations of non-strategic nuclear warheads, perhaps beginning with the locations where weapons have been removed.

## China

The Chinese government does not provide information about the size or composition of its nuclear stockpile. China has applied the principle of opacity to its limited nuclear deterrent to increase its survivability against U.S. and Russian attack. To our knowledge, China has only made one recent statement about the size of its nuclear arsenals. In 2004, the Chinese Foreign Ministry published a fact sheet that included the statement: "Among the nuclear weapon states, China … possesses the smallest nuclear arsenal."[235] Since Britain at that time had declared that it possessed less than 200 operationally available warheads, the Chinese statement could be interpreted to mean that China's nuclear arsenal was smaller than Britain's. Unfortunately, the Chinese statement is unclear as to whether "arsenal" refers to the total number of warheads or something else. In any case, the statement has not been updated. As of 2013, it is estimated that China has an arsenal of about 250 warheads.[236]

Over the years, the U.S. intelligence agencies have issued numerous statements about estimates of the Chinese nuclear arsenal. In March 1996, the CIA reported that, "Beijing currently has fielded a nuclear stockpile estimated by the Intelligence Community at between 200–300 weapons."[237] A decade later, in February 2006, Defense Intelligence Agency director Lt. Gen. Michael Maples testified before Congress that "China currently has more than 100 nuclear warheads," that deployed theater and strategic systems would likely increase and that "China has sufficient fissile material to support this growth."[238]

China's nuclear secrecy has fueled uncertainty, rumors and worst-case assumptions. In 2011, a statement in a Georgetown University Asian Arms Control Project study that China might have "as many as 3000 nuclear weapons" led to sensational news media headlines around the world.[239] In 2012, an article by retired Russian Col. General V. I. Yesin estimated that the Chinese arsenal might include 1600–1800 warheads, of which 800–900 are intended for operational deployment.[240] In late 2012, however, U.S. STRATCOM Commander General Robert Kehler explained "I do not believe that China has hundreds or thousands of more nuclear weapons than what the intelligence community has been saying, … that the Chinese arsenal is in the range of several hundred" nuclear warheads."[241]

The Chinese strategic arsenal is believed to be increasing, but how much and how fast is the subject of much speculation and uncertainty. In 2001, the U.S. National Intelligence Council projected that China by 2015 would have 75–100 warheads on missiles deployed primarily against the continental United States.[242] In 2011 and 2012, the Defense Intelligence Agency testified that China had "fewer than 50 ICBMs that can strike the continental United States" and said that China would "probably more than double that number by 2015."[243] Whatever the increase may be, the projections so far have promised too much too soon.

To increase transparency of its nuclear posture and counter such speculations, China should begin to provide basic information about its nuclear stockpile and modernization plans. This could include announcements about how many missiles of what type will be built and deployed in the coming decade, as part of a modernization program that includes land-based medium-range and intercontinental ballistic missiles, submarine-launched ballistic missiles, and possibly cruise missiles.[244] This should include information about how many warheads are to be carried by each system, a subject that is the root of much speculation and concern in other countries.

## Pakistan/India

Pakistan and India both claim to only want to have a minimum deterrent but both continue to increase and modernize their arsenals. Neither provides basic information about its nuclear arsenal. It is estimated that Pakistan currently has 100–120 warheads in its stockpile and that more are being produced. The Shaheen II medium-range ballistic missile appears to have become operational and two nuclear-capable cruise missiles are under development. A 60-km nuclear-capable rocket launcher (NASR) is also under development, suggesting that Pakistan is envisioning potential use of nuclear weapons below the strategic level.[245] India probably has about 90–110 warheads with more being built for longer-range Agni missiles, ballistic missile submarines, and possibly a cruise missile.[246]

Both Pakistan and India need to begin to provide basic information about their nuclear inventories and modernization plans. Opacity fuels uncertainty and worst-case planning on both sides.

## Israel/North Korea

Israel does not even acknowledge that it has nuclear weapons. Based on Israel's nuclear-capable delivery vehicles and leaked U.S. intelligence estimates, it is estimated that the stockpile is around 80 warheads for delivery by aircraft and ground-launched missiles.[247] There are speculations that Israel has modified cruise missiles to carry nuclear warheads for deployment on Dolphin-class submarines supplied by Germany. Other estimates for its nuclear stockpile range up to as many as 200 warheads.[248]

To provide information about its nuclear stockpile, Israel would have to break with fifty years of opacity. Given the considerable amount of information that has become available in the United States about Israel's nuclear efforts over the years, however, the existence of its arsenal is already well recognized.

Although North Korea has detonated three nuclear devices, there is no reliable public information that it has militarized its nuclear capability and built and deployed deliverable nuclear warheads. Most estimates of the size of North Korea's potential warhead stocks, based on the amount of plutonium that it has produced, range from eight to 12 warheads. While North Korea has not been transparent about the status and size of its nuclear arsenal, it has provided some information about its plutonium production and uranium enrichment program (see Chapter 1).

In sum, the nuclear weapon states have a very uneven and fitful record of transparency. The nuclear weapon states could provide much greater confidence in the international community that they are exercising restraint, that nuclear arms build-ups have ended, and that there is progress in reducing the size of nuclear arsenals if they were to regularly report the numbers of warheads in respective operational and total stockpiles. They should also disclose at least the histories of warhead types that are no longer in their stockpiles, and the history of warhead dismantlements. Doing so would also help increase trust and counter worst-case military planning between the nuclear weapon states.

# 5 Challenges of Producing National Fissile Material Declarations

In 1993, the U.S. government launched an Openness Initiative focused on nuclear information. Openness was a program designed to lift the veil of cold-war secrecy and move the Department of Energy (DOE) into a new era of international nuclear transparency. The administration hoped that releasing previously classified and sensitive information about the U.S. nuclear weapons arsenal would encourage other nations to release similar data, thereby promoting nuclear arms control, disarmament, and nonproliferation. The newly released information also:

- offered all Americans increased opportunities to participate in policymaking by providing the benefits of their collective expertise and information to governmental leadership; and

- enabled improved domestic oversight and accountability of the weapons complex and fact checking by independent nongovernmental groups.

The two most important publications resulting from the initiative were the reports on separated plutonium and highly enriched uranium (HEU) (hereafter, referred to as the U.S. declarations). The two declarations:

- stated current U.S. defense plutonium and HEU stocks as of 1994 and 1996, respectively;[249]

- detailed U.S. plutonium and HEU acquisitions from the mid-1940s forward;

- identified how much plutonium and HEU had been consumed or dispersed irreversibly; and

- checked how closely current plutonium and HEU stocks aligned with historic acquisition and usage records.

Subsequently, these initial declarations were reexamined and updated for plutonium as of 2009, and HEU as of 2004.[250]

In two similarly structured reports, the United Kingdom also announced the size of its military stockpiles of plutonium as of 1998 and HEU as of 2002 and outlined the acquisition and usage of these two fissile materials from the inception of its nuclear military program. [251] The reports were produced because the United Kingdom also "believes that transparency about fissile material acquisition for defence purposes will be necessary if nuclear disarmament is to be achieved."[252]

These reports provide unique case studies for other weapon states considering similar disclosures for furthering nuclear disarmament. Thus far, however, no other weapon state has carried out or publicly announced plans to carry out similar exercises.

This chapter is a case study of the U.S. declaration process. It provides context—offering a more complete picture of what happened and why; it identifies challenges and how they were met; it addresses whether the process is sustainable or not, and with what frequency, and it discusses lessons learned. Finally, it illustrates how results from the U.S. experience might be applicable to other weapon states considering fissile material declarations.

## Historical Approach and Data Sources

The objectives of the historical approach were to establish from the start of the U.S. nuclear program how much separated plutonium and HEU had been acquired by the United States, how much had been used, and then to compare this historic data with current stocks of plutonium and HEU. The United Kingdom used the same methodology before declaring the total size of its military stock of plutonium in 2000 and HEU in 2006.

The data available for constructing the U.S. historical accounting balances were largely based on paper records pre-1970 and electronic compilations post 1970. Pre-1970s data were compiled from both original paper records retained by sites and from summarized feeder reports based on information submitted by facilities and compiled, starting in the late 1940s, by the Atomic Energy Commission (AEC). Post-1970 figures, including current plutonium and HEU balances, were based on electronic data submitted directly from facilities to the Nuclear Materials Management and Safeguards System (NMMSS), the U.S. Government's national database jointly operated by DOE and the Nuclear Regulatory Commission (NRC).

The fissile material acquisition and usage categories developed in the 1940s are still in use today. Consequently, it was a relatively simple task to merge the pre and post-1970 records into one dataset for further analysis and for reconciliation with other data sources. The reporting unit for both plutonium and HEU was grams, subsequently summarized in either kilograms or metric tons for the purposes of simplifying the declarations.

***Pre-1970 Data.*** The inaugural years' (1940s to early 1960s) data were generally straightforward to confirm because there was no commercial nuclear industry and very few facilities handled these important strategic materials. The trustworthiness of the early figures was established by correlating acquisition and use data in early reports with data from other sources. For example, from 1945 through 1992, the United States conducted 1054 nuclear tests and two wartime detonations. The quantities of fissile materials expended in tests and wartime detonations were verified by adding the materials expended in each event and those totals compared with figures stated annually in the summary reports. Similar confirmatory comparisons were also made with other acquisition and use categories.

Information from anecdotal sources such as management reports from the operating sites to the AEC was generally deemed unreliable and not used. In addition to calculation reviews, site visits were also conducted to examine some of the pre-1970 primary source documents. Sites visited included Hanford, Idaho, Portsmouth, Savannah River, and West Valley.

***Post-1970 Data.*** As previously noted, the post-1970 figures were based on electronic data submitted directly by both U.S. defense and civilian facilities to the NMMSS database. In compliance with the terms of the U.S. voluntary offer to accept IAEA safeguards on peaceful nuclear activities, NMMSS is designated by the United States as its official state system of accounting for and control of nuclear material subject to IAEA safeguards under the agreement. As the official source for information regarding U.S. nuclear programs, NMMSS currently collects data from approximately 420 domestic nuclear facilities and supplies information to DOE, NRC, and ultimately other federal and international entities. The types of information in NMMSS include: possession, ownership, use, and shipment of selected nuclear materials within the United States as well as all exports and imports of such material.

## Fissile Material Stocks

Weapon grade plutonium and HEU stocks identified in the four U.S. and two UK declarations are shown in Table 5.1 The U.S. figures in the table include only weapon grade plutonium. Plutonium totals do not include either fuel-grade or reactor-grade plutonium (14.5 tons in 1994 and 14.1 tons in 2009). U.S. quantities do not include materials in the civilian fuel-cycle unless that material is owned by the U.S. government. UK numbers in the table also do not include civil material. Both the United States and the United Kingdom, along with seven other countries, declare annually and publically their stocks of civilian plutonium to the IAEA and the United Kingdom, France, and Germany do the same for HEU. Civil holdings are reported in accordance with the IAEA Information Circular 549 (INFCIRC/549), which are further discussed in Chapter 6.

Transitional materials, also commonly referred to as either excess or surplus, are fissile materials no longer needed for military (i.e., weapons and naval reactor use) programs and which are to be rendered unusable for weapons use (e.g. by downblending in the case of HEU or irradiation in MOX fuel in the case of plutonium). As shown in Table 5.1, the U.S. 2004 HEU declaration did not update the 1996 figure for transitional stocks; consequently, while the HEU stocks decreased by 54 tons from 1996 to 2004, the amount of HEU in transitional stocks at the end of 2004 was not released.

Not updating the 1996 surplus in 2004 was directly associated with the decade-long debate that preceded DOE's decision to release the 1996 report with only minor redactions in 2006. Increased resistance to public disclosure of nuclear information was spurred in part by security issues in the late 1990s and the aftermath of the September 11, 2001 terrorist attacks. These factors led to a government-wide reassessment of security policies including discussions on what information can be publicly disclosed and what needs to remain classified for nonproliferation and national security reasons. As a result, additional quantities declared excess and fissioned in naval and other reactors were not declared separately.

| | United States | | | | United Kingdom | |
|---|---|---|---|---|---|---|
| | 1994 | 1996 | 2004 | 2009 | 1999 | 2002 |
| **Weapon Grade Plutonium** | 85.0 tons | | | 81.3 tons | 3.51 tons | |
| Transitional | 38.2 tons | | | 43.4 tons | | |
| **HEU** | | 740.6 tons | 686.6 tons | | | 21.86 tons |
| Transitional | | 177.8 tons | | | | |

**Table 5.1. Stocks of weapon grade plutonium and HEU declared by the United States and United Kingdom.** The U.S. totals do not include either fuel-grade or reactor-grade plutonium.

***Commitment to Future Reduction.*** In 2005, the Secretary of Energy announced that in coming years, the United States would remove up to another 200 tons of HEU from nuclear weapons and prepare the material for other uses:

- Up to 160 tons to be used in fuel for naval reactors;
- 20 tons to be down-blended to LEU for civilian power reactors, research reactors or related research; and
- 20 tons to be reserved for space and research reactors that use HEU, pending development of fuels that will enable conversion to LEU cores.

In 2007, the Secretary of Energy announced that in the coming years, the United States would remove an additional 9 tons of plutonium from further use as fissile material in U.S. nuclear weapons increasing the 1994 total declared surplus from 38.2 tons to 47.2 tons. The 9 tons increase in plutonium transition stock was reduced by 3.8 tons for plutonium disposed in the 650-m deep Waste Isolation Pilot Plant (WIPP) in Carlsbad, New Mexico, resulting in the 2009 U.S. declaration of 43.4 tons. Once deposited in WIPP, plutonium is removed from U.S. accounts.

***Location of Fissile Stocks.*** The locations of the plutonium and HEU stocks identified in the four U.S. declarations are shown in Table 5.2 Both plutonium and HEU stocks decreased significantly between declarations: HEU decreased by 54 tons over eight years (an average of 6.75 tons per year); and, plutonium decreased 4.1 tons over fifteen years (<0.3 tons per year). The 54 tons decrease in total HEU was due primarily to down-blending to LEU.

The U.S. declarations provided a series of quantitative indicators for measuring longitudinal progress on material disposition and consolidation initiatives. For example, the 4.1 tons reduction in U.S. plutonium stocks since 1994 was made possible by the:

- opening of the WIPP in 1999 where disposal operations are expected to continue until 2070;
- completion of cleanup activities at the Rocky Flats Plant in 2005, which allowed improved estimates of the amount of plutonium in waste and remaining in the environment there; and,
- material consolidation and disposition activities, especially shipments from Hanford to Savannah River.

| | Plutonium (tons) | | | HEU (tons) | | |
|---|---|---|---|---|---|---|
| | 1994 | 2009 | Change | 1996 | 2004 | Change |
| DoD/Pantex/Y-12 [a] | 66.1 | 67.7 | 1.6 | 651.6 | 621.2 | −30.4 |
| Hanford Site [b] | 11.0 | 6.6 | −4.4 | 0.5 | 0.5 | 0.0 |
| Idaho Site [c] | 4.5 | 4.6 | 0.1 | 27.4 | 26.8 | −0.6 |
| Los Alamos [d] | 2.7 | 4.0 | 1.3 | 3.5 | 2.4 | −1.1 |
| Rocky Flats [e] | 12.7 | 0.0 | −12.7 | 6.0 | 0.1 | −5.9 |
| Savannah River [f] | 12.7 | 12.0 | 10.0 | 22.2 | 18.7 | −3.5 |
| Portsmouth [g] | | | | 21.7 | 0.9 | −20.8 |
| Other Sites [h] | 0.2 | 0.2 | 0.0 | 7.7 | 16.0 | 8.3 |
| **Total** | **99.5** | **95.4** | **−4.1** | **740.6** | **686.6** | **−54.0** |

**Table 5.2. Site specific U.S. weapon-grade plutonium and HEU stockpile declarations.**

a. Amounts in warheads or naval fuel in the possession of DOD, warheads and components at the DOE’s warhead assembly/disassembly facility and in DOE’s HEU storage and weapon-component production site. The increase in plutonium was due to the transfer of some weapon “pits” from Rocky Flats to Pantex.

b. Former plutonium production site.

c. Former naval-fuel reprocessing site and current HEU spent-fuel storage site. HEU in naval reactor spent fuel at Idaho is included in the DoD/Pantex/Y-12 number.

d. Nuclear weapon design and plutonium weapon “pit” production site. The increase in plutonium is due to transfers from Rocky Flats.

e. Former plutonium pit production site.

f. Former plutonium production site and now a plutonium consolidation and disposition site.

g. Former HEU production site.

h. Increase in HEU was associated with transfer of HEU for blend-down at BWXT in Lynchburg, VA and NFS in Erwin, TN.

## Reconciliation of History with Current Stocks

The mass balances for the four U.S. fissile material declarations are shown in Table 5.3 Total receipts, minus total removals, plus classified transactions and rounding, minus the cumulative inventory difference, equals the cumulative ending book inventory for the specified time period.

- Acquisitions include material production, and receipts from both international and civilian sources.

- Removals include material expended in nuclear tests and detonations, discards to waste, blend down of HEU to LEU, fission and transmutations, and exports. Classified transactions are exports or imports that remain classified for national security reasons.

- Inventory differences are the difference between the quantity of nuclear material held according to the accounting books and the quantity measured in a physical inventory.[253]

- The unrecognized gain or loss identified in the last row of Table 5.3 (calculated inventory minus physical inventory) is an indicator of the precision of the data reconstruction effort. The smaller the number, the greater the confidence in the data reconstruction effort.

| | Plutonium (tons) | | | HEU (tons uranium-235) | | |
|---|---|---|---|---|---|---|
| | 1994 | 2009 | Change | 1996 | 2004 | Change |
| Total Acquisitions | 111.4 | 111.7 | 0.3 | 866.1 | 867.3 | 1.2 |
| Total Removals | 9.2 | 14.0 | −4.8 | 243.3 | 274.5 | 31.2 |
| Inventory Difference | −2.8 | −2.4 | 0.4 | −3.2 | −3.2 | 0.0 |
| Classified Transactions | 0.1 | 0.1 | 0.0 | 0.3 | 0.5 | 0.2 |
| Calculated Inventory | 99.5 | 95.4 | −4.1 | 619.9 | 590.1 | −29.8 |
| Physical Inventory | 99.5 | 95.4 | −4.1 | 620.3 | 590.5 | −29.8 |
| Unrecognized (gain) or loss | 0.0 | 0.0 | | −0.4 | −0.4 | |

**Table 5.3. Changes in the plutonium and HEU mass balance equation identified in the four U.S. declarations.** Numbers are rounded to the nearest 0.1 tons.

As shown in Table 5.3, there was no difference between the calculated book inventory (resulting from the review of historical records) and the physical inventory for plutonium. The unrecognized gain for HEU was 0.4 tons, less than 0.1% of the physical HEU inventory. This indicates that the total acquisition category was understated by 0.4 tons. Because the differences for both materials were less than 0.1%, the record reconstruction was deemed to be accurate.

## Challenges of the declarations process

At least three valid concerns were addressed and overcome in the U.S. declaration process. These were: (a) explaining inventory differences; (b) clarifying discrepancies in waste numbers; and, (c) timing issues and perceived national security objections.

***Inventory Differences.*** Inventory difference, also commonly referred to as MUF (Material Unaccounted For), could reflect either failure to measure accurately all recognized material flows or failure to detect unrecognized material losses.

In addition, the total inventory differences during any time period could reflect the sum of many smaller differences. Each difference arises for one or more of the following: (a) difficulties with measuring plant holdup (i.e., materials in pipes, glove boxes, etc. even after plant "cleanout"); (b) measurement uncertainties due to wide variations in the concentrations of dilute materials such as waste; (c) measurement uncertainties within statistical variations, especially for the inadequate, primitive measuring technologies in the early years; (d) operational losses, such as accidental spills when accurate measurements had not been made before the loss; (e) human error during input of accounting system data; and (f) rounding errors.

Each inventory difference is investigated by operating contractors and reviewed by DOE in order to assign a likely cause to all differences and to assure that no significant loss, diversion, theft, or environmental contamination has occurred.

As shown in Table 5.3, the cumulative historical inventory difference for plutonium was 2.4 tons as of 2009; and for HEU as of 2004 was 3.2 tons (2.5% and 0.5% of physical inventory, respectively). Because these differences were tabulated across time, the concern was that public perception might consider these materials either lost or stolen. Cumulative inventory differences can also result in misleading impressions of the effectiveness of safeguards systems, since the reason for each year's difference were previously examined and accepted. Inventory difference data in the United States remains classified until a facility closes out its books at the end of each 12-month period, adjusted as appropriate on the basis of complete analysis of the past year's inventory difference.

The United States has been criticized both domestically and internationally for the size of its plutonium inventory difference. Most of this difference was attributed to measurement inaccuracies and uncertainties in the decades between the 1940s and mid-1970. Negative reaction to declaration information may well serve as a significant deterrent for other nations considering releasing similar information. Uncertainties, however, should not overshadow the importance of nation-states' willingness to release the data. Instead, they should serve to encourage revisiting and reanalyzing records, foster efforts at forensic analysis and search for additional data sets, and so promote improved material control and accounting.

***Misalignment in Waste Numbers.*** Nuclear material that is technically or economically unrecoverable and intentionally sent to waste is referred to as "normal operating loss." Normal operating loss (NMMSS waste) is removed from the material control and accountability inventory. The 1994 plutonium declaration revealed a 0.5 tons difference between normal operating losses (NMMSS waste) and waste numbers generated and reported by waste management programs (waste estimates).

No definitive explanation was found that reconciled the differences between the normal operating loss number as reported to NMMSS (3.4 tons) and waste program estimates (3.9 tons). In fact, the difference increased to 1.9 tons in the 2009 plutonium update. Explanations for the difference is attributed to inventory differences and methods used to calculate NMMSS normal operating losses numbers and waste estimates.

- NMMSS normal operating loss data track the removal of nuclear materials from the inventory. Quantities, often referred to as discards to waste, are accounted for in the material balance equation. They are determined by either direct measurements or by estimates based on sampling. All liquid wastes, for example, are sampled and analyzed prior to being sent to a waste tank.

- Waste estimates are also tracked separately by DOE waste management programs for environmental, safety, and health reasons after removal from the NMMSS inventory. Most waste values are directly derived from NMMSS; however, some quantities are based on re-measurement of discarded materials. Some of the recalculated estimates may be stated to a greater accuracy than the underlying measurement technologies support. Therefore, the quantities both measured and estimated have a wide margin of uncertainty associated with them.

Subsequent analysis indicated that the misalignment was largely related to inventory differences, especially for the Rocky Flats plutonium-contaminated waste shipped to Idaho from 1954 to 1970. The cause for these differences was attributed to significant limitations in measuring the radionuclide content of waste containers during the 1950s and 1960s.

Transparency and openness are two of the most important objectives of the declaration process. Unable to reconcile the differences in waste quantities, the DOE decided to publish both sets of numbers in both the 1994 and 2009 plutonium declarations.

***Timing and National Security Interests.*** The 1993 Openness Initiative did not set any frequency for updating the U.S. declarations. The Obama administration's decision to update was based on a number of interrelated factors, most notably support for increased transparency to bolster national and international security, and serving as a confidence-building measure.

From U.S. experience, a complete declarations cycle—from announcement of intent to publication—takes approximately two years. Declaration generation consists of five sequential steps: (1) data gathering and analysis, (2) reconciling numbers with previously released figures, (3) report writing, (4) declassifying, (5) and coordinating for public release. Each step depends upon completion of the preceding step. For example, declassification review cannot be initiated until steps 1 through 3 are complete.

1. The actual data gathering and analysis phase, can be accomplished in the United States in approximately three months. Some weeks of time will be involved in determining the ending inventory for the new period and comparing those figures with the quantities published in the previous declaration.

2. The net change in inventory is then reconciled and validated with facility transaction data as a cross-check to establish the trustworthiness of the new inventory number. Inventory values for HEU are reported both in terms of total uranium and contained uranium-235, the fissile isotope of uranium. Plutonium inventories are reported only in element weight.

3. Writing the report, can take approximately three additional months. Reconciling the new data with previously released information and explaining the reasons for changes are important components in establishing the credibility of the declaration process. The information contained in the U.S. declarations is based on the best available data. However accurate, the U.S. declarations retain uncertainties about how much fissile material was actually produced, processed, and discarded to waste during the period from the 1940s to mid-1970. Historical and logistical advances in nuclear material measurement systems with computer-aided tools to assist in the analysis of nuclear material accounting data have greatly increased U.S. declarations accuracy. Consequently, information contained in extant reports is subject to change only as additional or more detailed data become available during facility cleanout and waste operations. When this occurs, the differences may require additional explanation in the declaration.

4. Declassification, can take a year or more. A very important consideration affecting declassification of a declaration is the granularity of the data. For example, one aggregate number representing total stocks is much easier to declassify and release than many specific inventories spread across discrete locations. Consequently, for national security purposes, some inventory figures are grouped. Sensitive HEU inventories at the Y-12 Plant in Oak Ridge, Tennessee, and the Pantex Plant near Amarillo, Texas, together with material in the custody of the Department of Defense (DoD) including the Navy, were released as a single number in 1996 representing 88% of the total HEU.

5. Interagency coordination for public release of a declassified declaration, may take six months or longer. Coordination timetables vary not only with report granularity, but with the number of other governmental organizations and international stakeholders that must be consulted. The U.S. DoD and Department of State routinely review and approve each declaration. The timing of public release may also be set to coincide with nonproliferation meetings or discussions.

An important concern is whether or not the declaration process is sustainable—with specified updates or left only as a onetime event. Producing a comprehensive and verifiable declaration with complete detail is very time consuming and resource intensive. As previously discussed, much of the two year process focuses on declassification and coordination activities. Both activities require significant resource investments and collaboration among multiple governmental stakeholders with both policy and national security concerns. Some U.S. administrations have been less convinced than others about the priority to be accorded to transparency. The Bush Administration, delayed release of the first HEU report, completed in January 2001, until February 2006.

A declaration is a governmental policy statement. Important considerations include: government changes, world events, actions by other nations, other unrelated nonproliferation accomplishments, and national/international proclivity toward openness and transparency in general.

Additionally, the declaration process can also be impacted by other informational releases including the delivery of occasional papers at conferences, speeches, presentations, and program documents. For example, some environmental impact statements include information relating to quantities of fissile material used in various processes.

Given the complexities involved in preparing declarations for public release, annual updates are not feasible today from a declassification and coordination point of view.

Declassification is, and always will be, a staff-intensive activity; however, declassification review might become easier and quicker if guidance specific to declarations were developed.

From a current process point of view, five or more years between comprehensive declarations would seem to be a practical compromise. However, a case could be made for annual "aggregated" declarations, with more detailed comprehensive declarations every five years and as required to resolve outstanding issues or to report significant changes in fissile material stockpiles and management.

## Lessons Learned

When the United States prepared its initial declaration in 1994, there were no requirements that specifically identified what a declaration should contain. Initial thoughts by those assembling the data were to produce a report that contained tables with little or no explanatory narrative. However, the process quickly became a more complex process with many iteration cycles focused equally on explanations and numbers.

The importance of governmental-stakeholder relationships should not be underestimated. Public engagement, especially with stakeholders who were already committed and highly vested in the process, was essential in preparing the initial U.S. plutonium and HEU declarations. Meetings and consultations with non-governmental stakeholders helped clarify interest areas, define declaration content, and set declassification priorities. Such a participatory process helped both the government and stakeholders share opinions, insights, experiences and perspectives.

Every new declaration rekindles previous debates over transparency and secrecy. Generally, the more time between declarations, the more resistance to transparency. In the United States, resistance is primarily attributed to secrecy for national security (i.e., deterrence and uncertainties concerning capabilities); however, secrecy as a non-proliferation measure and secrecy because of historic traditions and conservative inertia are often factors.[254] Binding commitments to transparency and reporting could potentially change attitudes and mindsets.

It is essential to organize and permanently archive all materials used to construct the declarations. For the United States, this is especially true for materials created prior to 1969 when nuclear material accounting was first automated. Retaining this important body of evidence in one place is essential for establishing the authenticity and veracity of the declarations. Archives could potentially eliminate the time consuming effort to reconstruct historical information as data sources could be quickly searched to answer immediate questions or challenges. Data archives would also be both an important first step for supporting independent verification of the declarations and would provide information for nuclear archeology initiatives.

Today, there are still no internationally accepted protocols that specify the minimum information that declarations from weapon states should contain or the frequency of these declarations. There only exist the precedents set by the United States and the United Kingdom. A simplified approach similar to the civilian plutonium guidelines agreed to by the five NPT nuclear weapon states plus four non-weapon states with civilian plutonium programs (Belgium, Germany, Japan and Switzerland), could be a good starting point for developing a more comprehensive declaration protocol.[255] Following those guidelines, each of the nine countries annually declares to the IAEA its holdings of civilian plutonium as of the end of the previous year– see Chapter 6. In the case of the United States, that includes the amounts of government owned material that the United States has declared excess to national security needs (i.e., separated, remaining in spent fuel, and disposed to waste after termination of safeguards post-1998). One reporting inconsistency is that waste is dropped from the U.S. declarations but kept in the declarations to the IAEA.

The lessons learned from the four U.S. fissile material declarations include:

- Specific guidelines that can help decrease the time required to prepare an update for public release include using summary high-level aggregate numbers to hide detailed sensitive information. These principles were affirmed in the 2004 update of the 1996 U.S. HEU report which required only one year to assemble and release.

- Areas of particular concern to policy makers include: exports of plutonium and HEU for military purposes to nuclear weapon states whose identities are considered to be sensitive; lack of agreement between the official NMMSS records and information contained in other databases (e.g., environmental) that also tracked nuclear materials; and, differences between book and physical inventories (i.e., inventory differences).

- In general, countries with large defense stocks have significantly more flexibility in releasing more detailed information without compromising their national security. For example, countries such as the United States and Russia with large fissile material holdings, many facilities and programs (material production, weapons, naval propulsion, research and test reactors, research facilities, etc.) are able to group stocks into larger categories to protect information for national security reasons.

- To avoid the vagaries of political considerations, declaration details, including frequency, should be agreed by the countries concerned; for example, a template could be developed similar to the annual public reports to the IAEA under the agreed guidelines for the management of civilian plutonium.

- Annual updates of declarations of military stocks of fissile material do not seem feasible with current U.S. declassification and coordination arrangements. Given these arrangements, five or more years between declaration updates may be required if more than summary information is required. Developing a broad set of new declassification guidelines that allow routinizing the reporting process annually might be an option. However, given current classification rules, some use-categories of material will have to be to be combined to protect classified data. For example, excess data would be presented as one aggregate number for facilities whose inventories remain classified with no additional breakdown by facility.

- It is important for all nations to retain source data on nuclear material production and usage. Source data is critical to the believability and verifiability of declaration data. Since thousands of individual records can be used to prepare a declaration, it is critical to document how source data were used and combined to produce the declarations. This is especially true for updates and to inform personnel new to the declaration process.

## Conclusion

The United States and the United Kingdom have completed a task that other nuclear weapon states might consider to be worthwhile, however daunting. The difficulties of the task in some states might include a lack of a robust central accounting system and facilities that have incomplete or missing records of activities going back decades. As a result, compiling an accurate and comprehensive declaration—one that is ultimately verifiable by outsiders—can be difficult and time consuming.

A simplified declaration approach could offer nations a controllable task with several certain positive outcomes. At a minimum, an interim simplified declaration should contain: total fissile stocks at a specified time, quantities declared surplus to defense needs, and an explanation of changes since the previous report. Both public awareness and international security are well served by gaining more insight into nuclear material holdings and disposition.

In the longer term, a historical accounting also will be required. Even if they delay public declarations of such an account, therefore, the nuclear weapon states should not delay launching an effort to preserve historical records relevant to such an account and assembling a central accounting system within which this data can be organized and analyzed with protections against alteration.

# 6 The International Plutonium Guidelines

In late 1997 the Director General of the International Atomic Energy Agency (IAEA) received *notes verbales* (i.e., an unsigned communication) from the Permanent Missions to the IAEA of nine countries: Belgium, China, France, Germany, Japan, the Russian Federation, Switzerland, the United Kingdom and the United States. The note included the guidelines these governments had adopted to manage their inventories of civilian plutonium and recorded their intentions to make public annual declarations of their stocks of this material. The IAEA published the guidelines as INFCIRC/549 "Guidelines for the Management of Plutonium" (hereinafter referred to as the Guidelines) along with the first yearly declarations in March 1998. Since then, the participating states have submitted updates on a fairly regular basis.

This chapter describes the origins of the plutonium Guidelines, and the negotiations that led to the adoption of its various provisions. It then offers some thoughts on ways states could further enhance transparency of global stocks of plutonium and to broaden such measures to include HEU. Finally it suggests steps that the nuclear weapon-states could take to increase transparency of their surplus weapons materials beyond their declarations under the Guidelines.

## Origins and Negotiation of the Guidelines

In 1992 and 1993, IAEA Director General Hans Blix convened informal meetings with the five nuclear weapon states party to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) plus Germany and Japan in order to determine the possibility of increasing the transparency of the growing stockpiles of civil plutonium around the globe as well as of the surplus plutonium from dismantled nuclear weapons. The following year, the IAEA convened an unofficial study of ways to manage plutonium. However, the seven states consulted by Blix were reluctant to engage in such discussions in the same kind of forum that took place in the early 1980s on an international plutonium storage system (IPS) to implement Article XII.A of the Agency's Statute.[256] That forum was open to all IAEA member states.

The large number of states participating in the IPS discussions with widely divergent nuclear programs and nonproliferation policies and interests led to prolonged, disputatious and ultimately futile negotiations with no agreement achieved. The seven states consulted by Blix wanted to avoid a repeat of the unproductive IPS meetings and to limit any new discussions on plutonium to those states that possessed sizable stocks of plutonium and had a significant interest in responding to growing concerns about improving the transparency of their holdings of this material. Blix was unwilling to participate in a meeting that was not open to all IAEA member states, however.[257] Therefore the seven states, later joined by Belgium and Switzerland, decided to hold such discussions among themselves without any formal IAEA involvement and under the chairmanship of the United Kingdom.[258]

The nine states met periodically throughout 1997 to forge an agreement on the contents of the Guidelines. For the most part the negotiations of the Guidelines were not contentious, with the exception of one issue—a proposal by the United States that called for participating states to agree to reduce their stockpiles of plutonium (see below).

***Exclusion of Highly Enriched Uranium (HEU).*** Some states pressed to include HEU in the Guidelines, since this material is just as sensitive as plutonium, if not even more easily manufactured into a nuclear explosive. Others took the position that they had a legitimate interest in using plutonium as a commercial fuel, whereas there was no comparable interest in HEU. In addition, most international attention on HEU was focused on efforts to:

- Eliminate and/or reduce the use of this material, including the U.S.-Russian HEU purchase agreement, which aimed to down-blend surplus HEU from Russian nuclear weapons for use as fuel in civil nuclear reactors: and

- Persuade countries to convert HEU research reactor fuel to low enriched uranium and, in the case of the United States, to reinstitute its policy of taking back research reactor spent fuel containing U.S.-origin HEU.

None of these issues were suitable topics for a group focused on increasing the transparency of plutonium stocks. Moreover, some participants believed that, since many countries had HEU holdings and since they wanted to keep the group small, inviting a large number of additional participants would greatly complicate their deliberations.

However, in their notes verbales to the IAEA, Belgium, France, Germany, Japan, Switzerland, the United Kingdom, and the United States registered their belief that the management of HEU should be subject to similar guidelines and indicated their intension to consult with other like-minded governments in order to explore the possibility of establishing such guidelines for HEU. It is notable that the notes verbales of China and Russia do not contain this statement and that the seven other states have not initiated consultations on extending the guidelines to HEU. Nonetheless, in 2004, France, Germany and the United Kingdom began to include declarations of their civilian HEU stocks in their annual plutonium declarations.

***Transparency and the Publication of Information on Plutonium Holdings.*** The initial focal point of the group's discussion was on making plutonium stocks more transparent by publishing information on their stocks of this material on a regular basis.

The first question was what plutonium was to be covered by the Guidelines. The group focused their attention on weapon-usable plutonium and agreed (in Paragraph 2 of the Guidelines) that they would make public information on their holdings of:

- separated plutonium;

- plutonium contained in unirradiated mixed oxide fuel elements;

- plutonium contained in other unirradiated fabricated goods;

- plutonium in the course of manufacture or fabrication or contained in unirradiated goods in the course of manufacture or fabrication.[259]

Notably, Paragraph 2 does not specify plutonium contained in irradiated or spent fuel. Some states felt that including estimates of the much larger quantities of plutonium in spent fuel would contrast sharply with the smaller but still sizeable quantities of unirradiated plutonium. The group resolved this issue by allowing each participating state to publish such estimates if it chose to do so (see Paragraph 14 of the Guidelines). All participants but China have published estimates of plutonium in their spent fuel holdings.


**Figure 6.1. Spent fuel pool at China's pilot reprocessing plant.** The plant underwent hot testing in 2010, and China reported a civilian stockpile of 13.8 kg of separated plutonium as of the end of that year. No change was declared for the stockpile as of the end of 2011. The plant could separate up to 500 kg of plutonium per year. China does not report the amount of plutonium in spent fuel. *Source: CCTV-13.*

***Coverage.*** The group agreed (Paragraph 3) that, "These guidelines apply to the management of all plutonium in all peaceful nuclear activities, and to other plutonium after it has been designated by the Government concerned as no longer required for defence purposes."[260]

Excluding from the guidelines plutonium in military use was not a controversial or divisive issue in the discussions. The nuclear weapon states predictably opposed including such material in their declarations, and the non-nuclear weapon states did not press them to do so. However, the group decided that the Guidelines should apply to plutonium that had formerly been in military use and that had been declared as "no longer required for defense purposes." This terminology was used because certain states had difficulties in using other formulations such as "excess" or "surplus" weapons plutonium.

In addition, in their *note verbales* to the IAEA informing the Agency of their adherence to the Guidelines, Russia and China stated their intention to include their surplus military plutonium in their declarations only after it has been transferred to peaceful use. (China has not declared that it has any excess military plutonium.)

The members of the group also agreed that data to be published would not provide details on forms, isotopic composition or locations of the material but would be limited to national, aggregate quantities of plutonium holdings.

***Fuel Cycle Plans.*** The group also agreed to try to improve public understanding of their plutonium programs by issuing occasional brief statements explaining their national fuel cycle strategies and their general plans for managing their holdings of plutonium (Paragraph14). Participating states have periodically provided such narrative descriptions of their plutonium management policies with their declarations.

***International Standards.*** Some participants believed that merely publishing information about plutonium stocks was an insufficient means of promoting public confidence. It was, therefore, suggested that the group consider reaffirming their commitments to nonproliferation, safety and physical protection with respect to their stocks of plutonium. The UK chairman prepared a draft containing such commitments. Since the proposed text was largely a confirmation of commitments they had already made, the members of group easily accepted it with few changes.

The final text of the Guidelines provides that the covered plutonium be managed in accordance with the adherents' obligations under the NPT and the EURATOM Treaty as well as international standards agreements or conventions on nuclear safety, radiological and physical protection. Members also agreed to subject their plutonium stocks to an effective system of nuclear material accountancy and control.

The group did not make any new commitments on safeguards. The non-nuclear-weapon members of the group had already submitted all their plutonium to IAEA inspection by virtue of their safeguards agreements with the Agency. As for the nuclear weapon states, the 1995 document on Principles and Objectives of the 1995 NPT Review and Extension Conference had stated," Nuclear fissile material transferred from military use to peaceful nuclear activities should, as soon as practicable, be placed under IAEA safeguards in the framework of the voluntary safeguards agreements in place with the nuclear weapon states. Safeguards should be universally applied once the complete elimination of nuclear weapons has been achieved." The phrase "as soon as practical" stemmed from certain security, legal and economic concerns that the nuclear weapon states had with placing plutonium no longer required for defense purposes under IAEA safeguards. Some of the plutonium was still in the form of classified weapons components, and the cost of dismantling the components was sensitive information. In addition some states had mixed civil-military facilities.

In their *notes verbales* to the IAEA, the United States, the United Kingdom and France each stated its intention "to take as soon as practicable such steps as may be necessary to submit to safeguards by the IAEA on a voluntary basis under its safeguards agreement with the Agency (and, in the case of the France and the United Kingdom, under the EURATOM Treaty), all plutonium in peaceful nuclear activities, including any plutonium transferred from military activities to peaceful nuclear activities."

**Figure 6.2. The UK plutonium store at Sellafield, in West Cumbria.** It holds more than 100 tons of plutonium, including former weapon plutonium declared excess. *Source: British Nuclear Fuels and IAEA ImageBank.*

The two other nuclear weapon states—Russia and China—were not as broad, and each merely stated its intention, "...to take as soon as practicable such steps as may be necessary to submit to safeguards by the IAEA on a voluntary basis under its Safeguards Agreement with the Agency any plutonium transferred from military activities to peaceful nuclear activities." China and Russia did not commit to cover all their civil plutonium, since their voluntary safeguards agreements are limited to only a few peaceful nuclear facilities, whereas the voluntary safeguards agreements of the other NPT nuclear weapon states apply to all their civil nuclear activities.

Russia and the United States noted that they had begun discussions with the IAEA on provisions for some kind of inspection regime associated with former weapons materials. As of 2013, discussions were on-going with regard to IAEA monitoring of the fabrication of excess Russian and U.S. weapon-grade plutonium into MOX fuel, although as noted in Chapter 1 the future of the U.S. MOX program is now in doubt.

The subject of applying safeguards to the plutonium covered by the guidelines under existing safeguards agreements was not a controversial issue. The non-nuclear weapon states did not press the nuclear weapon states to go beyond the above commitments.

The participating states undertook no new commitments in agreeing to adhere to these treaties, conventions, norms and practices. However, some of the participants did make new pledges concerning international transfers of plutonium covered by the Guidelines. For example, the Guidelines require that, before any shipment of separated plutonium exceeding 50 grams to one recipient country in any period of 12 months is undertaken, the supplying government will require "the provision by the intended recipient of a certificate stating, besides the quantity, the approximate date of delivery, the final destination and end-use, and the timetable foreseen for utilisation."[261] The European members of the group had already adopted similar guidelines in 1984,[262] but no other international guidelines or treaties contained these pledges for the non-European adherents to the Guidelines. The EU guidelines have a practical impact largely on France and the United Kingdom.

***Reduction of Stocks.*** As noted above, the text concerning the management of plutonium stocks turned out to be the most controversial issue taken up by the group. This topic arose as a result of pressure by the United States to persuade other participants to make a political commitment, or at least to state their intention, to reduce their stocks of plutonium. The U.S. initiative was an effort to carry out certain objectives set out in President Clinton's nonproliferation policy statement of September 27, 1993, to address concerns about the growing global stockpiles of unirradiated plutonium. That statement said, among other things,

> "The U.S. will undertake a comprehensive approach to the growing accumulation of fissile material from dismantled nuclear weapons and within civil nuclear programs. Under this approach, the U.S. will:
>
> - Seek to eliminate where possible the accumulation of stockpiles of highly-enriched uranium or plutonium, and to ensure that where these materials already exist they are subject to the highest standards of safety, security, and international accountability.
>
> - Explore means to limit the stockpiling of plutonium from civil nuclear programs, and seek to minimize the civil use of highly-enriched uranium."

Throughout the discussions, the United States made repeated efforts to propose various formulations that would reflect a commitment or goal, however qualified, in the Guidelines to reduce plutonium stocks. However, other members of the group strongly resisted such language.

The members of the group finally reached compromise language in Paragraph 13 of the Guidelines where each adherent states it "is committed to management of plutonium in ways which are consistent with its national decisions on the nuclear fuel cycle and which will ensure the peaceful use or the safe and permanent disposal of plutonium." They also agreed that, when forming such decisions, they would take into account a number of factors, including:

> "the need to avoid contributing to the risks of nuclear proliferation, especially during any period of storage before the plutonium is either irradiated as fuel in a reactor or permanently disposed of; the need to protect the environment, workers and the public; the resource value of the material, the costs and benefits involved and budgetary requirements; and the importance of balancing supply and demand, including demand for reasonable working stocks for nuclear operations, as soon as practical."

The language on the "importance of balancing supply and demand" fell short of the U.S. objective of obtaining the group's agreement on a language to scale back existing accumulations of this material. Moreover, the formulation was not only qualified, but also avoided any commitment to balance supply and demand of plutonium. Rather such balancing was only one factor that adherents to the Guidelines would take into account in developing their national fuel cycle strategies.

The U.S. goal of reducing stocks was perhaps unrealistic from the outset, since several members of the group had large imbalances of supply and demand of plutonium and limited or no near-term options for burning their excess stocks of this material in their civil nuclear reactors or otherwise disposing of it.

- In the late 1990s, the United Kingdom had close to 60 tons of unirradiated civil plutonium with no apparent way forward for reducing this stock. It still doesn't, although, now that it has decided to end reprocessing, it is examining options for disposing of its 100 tons of separated civilian plutonium plus 17 tons that it is holding for Japan.

- Russia in 1998 had approximately 30 tons of civil plutonium and substantial stocks of military plutonium. (It now has about 50 tons of civilian plutonium.) The Russian plan was (and still is) to use this material as fuel in their breeder reactor program, an ambition that will not be realistically achieved for decades since, under its plutonium disposition agreement with the United States, at least 34 tons of Russia's excess weapon-grade plutonium is to be used first.

- Japan had over twenty tons of irradiated plutonium stored in Europe in the late 1990s, and although Tokyo had plans to recycle this material in its peaceful nuclear program, it had not yet begun to do so at any large scale. Japan's recycle program has been subject to continued delays, while Japanese owned plutonium in Europe has increased to 35 tons as of the end of 2011 as the reprocessing of its spent fuel continued apace in accordance with the contracts with the French and the British.[263]

**Figure 6.1. Bottles (left) being filled with plutonium-oxide in shielded glove-boxes (right) at Russia's Mayak RT-1 reprocessing plant.** Most of Russia's 50 tons of civilian plutonium is stored at Mayak and Russia plans to use this plutonium as fuel for breeder reactors. *Source: Ilya Yakovlev.*

Hence these states found themselves unwilling to consider language on reducing their stockpiles in 1997. As might have been expected, balancing supply and demand of plutonium stocks by the adherents to the Guidelines has not been achieved, as civil stocks plutonium have grown significantly because the separation of plutonium has continued while its use as fuel in commercial power reactors in many countries has not kept pace.

A few states have their plutonium recovered from reprocessing abroad, fabricated into mixed-oxide (MOX) fuel elements and used as fuel in their reactors. The declarations of these countries are not that meaningful because they depend upon whether or not the MOX fuel has been loaded by the end of the year.

## Accomplishments and Implementation of the Guidelines

Under the Guidelines the nine states agreed to increase transparency on their plutonium stocks by publishing annual statements of their holding of all unirradiated plutonium subject to the Guidelines and occasional brief statements explaining their national strategies for nuclear power and spent fuel. Some also agreed to provide estimates of the plutonium contained in their holdings of spent civil reactor fuel. They also reaffirmed their existing commitments to manage their civil plutonium responsibly.

Making this information public was a new step for these countries. Their principal achievement was that they allowed for the public monitoring of, and increased public confidence concerning, some, but not all, global stockpiles of this material. Still the Guidelines constitute voluntary statements of policy intentions and are neither legal obligations nor political commitments.

It has been almost 15 years since the Guidelines entered into effect. In general the members of the group have lived up to their commitments under the Guidelines by submitting their promised declarations of their plutonium holdings in a timely manner, although some states have not provided all of the information that the Guidelines call for or filed their declarations on time.[264] The Guidelines' accomplishments, while valuable in promoting transparency, are limited and modest.

## Time for Additional Transparency Measures

It is now time for the participants in the 1997 discussions to review the Guidelines and to determine whether there are ways to improve their declarations and to expand their scope.

For example, one way to improve the existing declarations would be for all nine participating states to follow the example of Japan and publish a more detailed breakdown of their holdings of civilian plutonium by site.

The Final Communiqué of the 2010 Nuclear Security Summit stressed the importance of promoting measures "to secure, account for, and consolidate" HEU and plutonium. This goal would be advanced by increasing the number of states adhering to the Guidelines, finding ways to improve the declarations on plutonium and expanding them to include HEU and military materials.

In their *notes verbales* submitted to the IAEA, the nine adherents to the Guidelines expressed their hope that other States that separate, hold, process or use plutonium in their civil nuclear activities will adopt policies similar to those in the Guidelines. However, members of the group have not thus far made any genuine efforts to persuade other countries to adhere to the Guidelines. They should now take the initiative to urge additional countries that have civil unirradiated plutonium stocks to publish their holdings of plutonium.[265] There are presently two such countries: the Netherlands and India.

The Netherlands reprocesses its spent fuel in France and has begun to recycle the separated plutonium as MOX fuel, in its single reactor. It therefore possesses unirradiated plutonium only during the intervals between when the MOX is delivered and when it is loaded.[266] Persuading India to submit declarations of its holdings of such material would be important. India has several tons of unirradiated reactor-grade but weapon-usable plutonium that it plans to use in its breeder reactor program.

Whether India would be prepared to take this step remains uncertain since it has declined to submit its breeder program to IAEA safeguards, leaving open the option to use the reactor-grade plutonium for weapons or to use its prototype breeder reactor to produce weapon-grade plutonium for nuclear weapons. India has been seeking to convince the international community of its nonproliferation credentials in the context of its successful efforts to negotiate a peaceful nuclear cooperation agreement with the United States and to have the Nuclear Suppliers Group exempt New Delhi from its ban on nuclear cooperation with states that do not have comprehensive IAEA safeguards. It is currently attempting to join the NSG. New Delhi could enhance its nonproliferation standing by adhering to the Guidelines and publishing information on its holdings of its unirradiated civilian plutonium. Such a step would increase international confidence in the peaceful nature of this aspect of its program. It might also reduce suspicions in Pakistan about the potential weapons use of India's reactor-grade plutonium and breeder program.

Beyond states with unirradiated civil plutonium, it might be useful to consider encouraging all states with peaceful nuclear programs to join the Guidelines and to report on their holdings of plutonium contained in their spent fuel.

The group should also consider ways to include civil HEU stocks in the Guidelines or to develop a separate set of guidelines for HEU. HEU is no less sensitive than plutonium. Although adherents are free to declare their stocks of civil HEU, only three countries—France, Germany and the United Kingdom—provide declarations on their holdings of this material.

Adherents to the Guidelines should meet to consider the inclusion of HEU in the Guidelines. This could be accomplished by expanding the Guidelines or perhaps drafting a separate set of guidelines to cover HEU that would contain new language regarding the management of this material as well as a commitment to reduce, consolidate and eliminate HEU from civil nuclear programs, including converting research reactors from HEU to low-enriched fuels. Achieving agreement on this issue has proved easier than reducing stocks of plutonium, since there seems to be an emerging consensus on the importance of minimizing the use of HEU.

The 2010 NPT Review Conference final document encouraged "states concerned, on a voluntary basis, to further minimize highly enriched uranium in civilian stocks and use, where technically and economically feasible." The 2012 Seoul Nuclear Security Summit encouraged states to "take measures to minimize the use of HEU, including through the conversion of reactors from highly enriched to low enriched uranium (LEU) fuel, where technically and economically feasible, taking into account the need for assured supplies of medical isotopes." It also encouraged states in a position to do so, by the end of 2013, to announce voluntary specific actions intended to minimize the use of HEU and to promote the use of LEU fuels and targets in commercial applications such as medical isotope production, and welcomed relevant international cooperation on high density LEU fuel to support the conversion of research and test reactors.

The nine states adhering to the plutonium Guidelines could invite other states possessing stocks of HEU to join in the development of a new set of guidelines for plutonium. However, this would mean a large, more unwieldy and more diverse group. Alternatively, the nine could agree on new HEU guidelines and invite other states with HEU stocks to adhere to them. Some states may argue that there is no need for international guidelines on managing HEU, since the Seoul Communique has already endorsed the basic elements that would compose such guidelines. However, there has been no agreement on undertaking transparency measures on HEU stocks. At the very least, states possessing HEU could agree on a new set of international guidelines that would include the annual publication of such stocks.

***The Nuclear Weapon States.*** The United Kingdom, the United States and Russia have declared that a significant portion of their military stocks of plutonium that has been declared excess will be used for civil purposes only. The United Kingdom and the United States include unirradiated plutonium declared as excess to military requirements in their declarations under the Guidelines. China has not declared any excess military plutonium under the Guidelines, and although Russia has announced it has approximately 50 tons of plutonium excess, of which about 37.8 tons is unirradiated, Moscow does not include its excess military plutonium in its declarations under the Guidelines.[267]

China and Russia should be encouraged to follow the example of the United Kingdom and the United States and declare their stocks of their surplus military material as soon they have designated plutonium and HEU excess to their defense needs and not delay such declarations until these materials have been physically transferred to peaceful use.

Another way to improve on the existing Guidelines would be for the nuclear weapon state adherents to declare their civil and excess military stocks of plutonium separately rather in an aggregate form.

Perhaps the most important next step for the five nuclear weapon states would be to expand their declarations into the military sphere. For example they should:

- Publish information on the historic production of plutonium and HEU for their defense programs. The United States and the United Kingdom have already done this for their military plutonium and HEU.

- Declare more plutonium excess to military requirements under the Guidelines.

- Declare total military stocks of plutonium.

- Publish their stockpiles of nuclear weapons. The Final Document of 2010 NPT Review Conference "notes the increased transparency of some nuclear weapon states with respect to the number of nuclear weapons in their national inventories and encourages all nuclear weapon states to provide additional transparency in this regard."

- State their intention not to reintroduce stocks declared as excess to defense needs back to military uses. It is not clear that all the nuclear weapon states will be willing to make legal or even political commitments to abstain from returning the excess weapons plutonium or HEU to their defense programs, but they might be persuaded to include a statement in a revised set of guidelines that they have no intention of remilitarizing the surplus plutonium they declare under the guidelines.

Taking steps such as declaring both civil and military fissile material stocks, publishing information on the history of the production of these materials as well as increasing the transparency of the nuclear weapon inventories would be an important step toward fulfilling the obligations of the nuclear weapon states under Article VI of the NPT.[268]

The non-NPT nuclear weapon states should also be encouraged to declare their civil and military stocks of plutonium and HEU, although India, Israel and Pakistan are unlikely to make any such declarations unless they are part of regional arms control arrangements.[269] However, publishing their civil and military stocks of fissile material could be a first step in establishing confidence-building measures by these states.

***Beyond Transparency to Safeguards.*** While transparency measures can provide an important contribution to public confidence about fissile material stocks, placing materials under IAEA or regional safeguards would be of much greater consequence.

The Guidelines include only information on the aggregate quantity of this material in their respective countries. No one verifies the accuracy of these declarations. By contrast, under their safeguards agreements with IAEA and EURATOM, most states provide detailed information on the quantities, forms and isotopic composition and other facts concerning their plutonium holdings for each "material balance area" in each of their peaceful nuclear facilities. This information is not made public for security or proprietary reasons, but submitting fissile materials to international inspections goes beyond transparency because applying safeguards means verification of fissile materials declarations.

The non-nuclear weapon states have placed all their nuclear materials under international safeguards. The United States, the United Kingdom and France have placed their peaceful nuclear materials under their respective voluntary safeguards agreements with the IAEA.[270] In addition, the United States and Russia have asked the IAEA to establish verification measures with respect to their excess weapon-grade plutonium disposition programs covered by the Plutonium Management and Disposition Agreement under which each agreed to dispose of 34 tons of its surplus weapons plutonium.

Unfortunately the voluntary safeguards agreements of the nuclear weapon states have important limitations. With a few exceptions, the IAEA does not actually apply safeguards in the nuclear weapons states due to a lack of financial resources. This situation is not likely to change in the near-term. In addition, the voluntary safeguards agreements of the United States, Russia and China with the Agency allow each of those states to withdraw nuclear materials or facilities eligible for the application of IAEA safeguards.[271] It is not likely that any NPT nuclear weapon states would in the foreseeable future amend its voluntary safeguards agreement to eliminate this right to withdraw materials. However, they should consider making statements in a revised version of the Guidelines that they do not intend to return any of their fissile stocks to military use.

In addition, China and Russia, whose voluntary safeguards agreements are limited to a few civil facilities, should broaden the number of facilities eligible for safeguards under their voluntary offer safeguards agreements with the IAEA.

Revising the Guidelines or developing a new set of guidelines containing the steps outlined above would be responsive to repeated decisions by various Review Conferences of the NPT to increase transparency and place surplus military fissile materials under IAEA safeguards.

# 7 Nuclear Archaeology and Warhead Verification Collaborations

The end of the Soviet Union in the early 1990s opened a period of unprecedented co-operation between nuclear and military specialists in the United States and Russia. This included research and cooperative development of methods and techniques that might be used for monitoring of nuclear warhead reductions and to verify declarations of fissile material production. This chapter provides details on the progress that has been made and some lessons learned for future cooperative transparency projects.

## Early U.S.-Russian Cooperation

The institutional arrangements that made U.S.-Russian cooperation possible after the Cold War included the December 1991 U.S. Nunn-Lugar Cooperative Threat Reduction program and the bilateral Gore-Chernomyrdin Commission set up in June 1993. Under the Nunn-Lugar program, broad assistance was provided to Russia in the area of strategic nuclear weapon reductions. The Gore-Chernomyrdin Commission yielded the March 1994 Mutual Reciprocal Inspection (MRI) Agreement between U.S. Secretary of Energy Hazel O'Leary and Russian Ministry of Atomic Energy Minister Victor Mikhailov, which laid a basis for cooperation on increasing transparency, including on verification of fissile material from the dismantling of nuclear weapons.

The cooperative work during these early days, when the Russian nuclear laboratories were in financial crisis, mostly took the form of U.S. specialists managed by the Department of Energy coordinating Russian laboratory and paper studies concerning nuclear arms reduction. This work proved quite fruitful technically. As important were the professional and collegial relationships formed between nuclear weapons institutions and nuclear weapons specialists from both countries that still today make U.S.-Russian technical dialogue on often esoteric verification matters relatively straightforward.

Even though MRI was never implemented, the joint research and development work that it enabled evolved into the U.S.-Russian Lab-to-Lab program, which ultimately was subsumed in the late 1990's into the U.S.-Russian Warhead Safety and Security Exchange (WSSX) effort. This effort involved cooperative work between U.S. and Russian nuclear specialists on joint "hypothetical" studies (as the Russian specialists liked to call them at the time) about possible warhead dismantlement on-site monitoring technology and methods.

The March 1997 Helsinki Summit between Presidents Clinton and Yeltsin resulted in a U.S.-Russian agreement to begin negotiations that would include:

> "measures relating to the transparency of strategic nuclear warhead inventories and the destruction of strategic nuclear warheads and any other jointly agreed technical and organizational measures, to promote the irreversibility of deep reductions including the prevention of rapid increase in the number of warheads."[272]

In the midst of this U.S.-Russian cooperative research, negotiation began to establish a monitoring and inspection agreement for the Fissile Material Storage Facility being constructed with U.S. funding at Russia's Mayak nuclear site. To fund completion of this facility at Mayak, the U.S. Congress stipulated that the Russian material (initially, only weapon-grade plutonium) must be of weapons origin, i.e., that the material came from dismantled Russian nuclear warheads. The "weapon-origin" would have to be verified. This resulted at times in what can only be described as a very contentious negotiation.

However, because of the breadth of the cooperative research and development activities described earlier, the U.S. and Russian technical advisors supporting their respective negotiators were quite familiar with the full range of possible methods and technologies for identifying weapon-origin material, including their shortcomings and strengths, and had a good understanding of the risk of intrusive inspections compromising sensitive information. For the most part, the technical debate around the use of warhead attributes, or the use of high-security safeguard technologies did not require long and detailed explanation. The salient issues could be dealt with from the start using the same jargon.

The key role of collaborative research and development of technical verification measures for prospective negotiating parties seeking a path to deep nuclear reductions became evident in 2000–2001, when technical warhead verification demonstrations took place in both the United States and Russia. Classified warhead nuclear items were examined using radiation-based attribute measurement systems under the watchful eyes of both Russian and U.S. specialists without the release of sensitive information. In one demonstration at the U.S. Oak Ridge Y-12 Plant, a classified item was ground to pieces behind a special physical barrier in the presence of Russian and U.S. observers.

The U.S-Russian cooperative effort described here was not the only program of this kind. In 1998 specialists from the UK Atomic Weapons Establishment began a comprehensive program of research into verification measures associated with global nuclear arms control. As authorized by the 1958 U.S.-UK agreement of Exchange of Information by Visit and Report (EIVR-58), this effort eventually expanded in 2000 to include joint meetings and exercises involving specialists from both the United Kingdom and the United States in each other's facilities.[273] In parallel, and widely reported, the United Kingdom and Norway have held similar discussions and exercises.[274]

## Warhead Measurements

Exploiting the penetrating radiation from fissile materials to verify nuclear arms treaties has been the objective of a great deal of the verification research and development effort over at least the last 20 years. The two basic approaches are the use of warhead and warhead component and materials "attributes" or the use of radiation signature "templates."[275] This work expanded somewhat to include non-radiation template signatures, such as complex impedance and acoustic signals, in the hope of finding signatures that were highly differentiating but not inherently classified.[276] As noted above, there has been robust joint research in this area with Russian specialists on an unclassified basis, at least until 2003. On several occasions, this included controlled measurement demonstrations using classified objects.[277]

For a nuclear warhead, an attribute can be defined as an inherent measureable characteristic of the object under inspection, even if in a container, that can permit unclassified discussions and agreement for verification and compliance determinations. A template is a characteristic physical signature of an item containing enough detail that it can be used to confirm that the signature from a second inspected item is a sufficient match and so to determine whether the inspected item is a duplicate.

Warhead item attributes that have been investigated with some success include: item mass, presence and isotopics of fissile material, presence of high explosive, form: rubble versus intact object, object symmetry, and age of fissile material.[278] It is doubtful that an attribute approach by itself would be good enough to confirm that an object is or is not a nuclear warhead. It may however serve for confidence building and transparency.

If nuclear weapon state treaty partners decide to share what is now considered classified weapons information, the distinctions between attribute approaches and template methods begin to blur, and confirmatory processes may become less problematic. All of this needs much more definitive research and peer review—the type of work that has taken a back seat to prototype system design and demonstration activities to date.

As suggested earlier, two past hardware system demonstrations are particularly worthy of additional discussion. The first is the 1997 measurement campaign on thirty-three real warhead items at the U.S. Pantex Plant. The second is the August 2000 prototype attribute measurement held at Los Alamos National Laboratory for the U.S.-Russian Mayak Transparency Monitoring and Inspection Negotiations, where the issue was one of weapon-origin and which involved a classified U.S. item.

With the objective of the Pantex campaign being to gain a much better understanding of the efficacy of ionizing radiation measurements to monitor warhead dismantlement, the work had to be conducted at a classified level. An unclassified summary was made available and was briefed to Russian technical specialists at a joint meeting under the WSSX agreement held at Sarov, Russia, the site of the All-Russian Research Institute of Experimental Physics (VNIIEF) in 2001.[279]

During the course of the three-week measurement campaign, thirty-three actual warheads and warhead nuclear components were examined while they remained in containers. The results were:

1. Effective discrimination by type of warheads, pits, and secondaries was demonstrated;

    - the radiation signatures of different warhead types were clearly distinguishable (five types examined)

    - the signatures of different (thermonuclear) secondary types were distinguished, but only limited data were available (two types examined).

2. Signatures of different pit types were easily distinguished except for two very similar all-plutonium pits (seven types examined):

- the individual (serial number) identification is a very difficult problem due to the very close tolerances employed when constructing warheads of the same type;

- one team provided evidence that such distinctions may be possible using minor-isotope information;

- the study of a larger population of warhead components will be necessary to definitively determine the utility of minor isotopes.

The Attribute Measurement System used in the 2000 Los Alamos demonstration for Mayak Fissile Material Storage negotiators had been jointly developed by Lawrence Livermore and Los Alamos National Laboratories. The purpose of the demonstration was to show Russian specialists how sensitive plutonium items could be shown to be of "weapon-origin." The demonstration to the Mayak Fissile Material Storage negotiators went flawlessly. Several attributes were measured and results were presented using a bank of red lights and green lights to indicate whether or not attribute threshold conditions had been met without revealing any classified information.[280]

To summarize, the basic efficacy of using attributes for transparency purposes in warhead monitoring is reasonably well understood. More research is needed on promising non-nuclear signatures of nuclear warheads.

### Unique Identifiers

Available technologies for reliably counting nuclear warheads and maintaining a chain of custody of these items until they are verifiably rendered useless are imperfect. Methods such as the host country manufacturing serial numbers, usually associated with a right of on-site inspection, have a high transparency value, but have limited reliability if there are concerns about tampering of a seal or if there is need to independently confirm numbers of treaty limited items such as warheads. Attacks to defeat a tag or a seal fall into three basic categories: removing and replacing without detection, counterfeiting the physical tag or seal, and causing the authenticating reader to give an erroneous confirmation.

While tags and seals for safeguarding nuclear material and items and other sensitive items (e.g. diplomatic pouches) had been in use for many years, their use for arms-control purposes became more central to U.S. policy during the START negotiations. It was decided to field a very high security approach, all aspects of the design and manufacture of which would be completely known to both parties. The United States wished to negotiate and deploy technology to uniquely identify the treaty-limited first-stage ballistic missile rocket motors. At first, there was no formal metric of how much resistance to tampering was good enough, but any proposed method that was believed to have an obvious defeat was not considered very seriously by the decision makers. The metric that was agreed to was the cost in time and money of a defeat. If a perceived or demonstrated defeat could only be envisioned that was in the same realm as the cost of constructing a whole new rocket motor, that was good enough.

The U.S. Departments of Defense and Energy formed a Tagging Laboratory Advisory Group (the TAGLAG) of scientists, engineers, and security specialists. Only two technologies ended up gaining support: the reflective particle tag from Sandia National

Laboratory and the ultrasonic intrinsic tag from Pacific Northwest National Laboratory.[281] It took almost four years for this work, with costs in a few tens of millions of dollars. In the end, the United States offered to remove the requirement for high security tags as a matter of policy; an offer the Russian side reportedly accepted with enthusiasm.

Four lessons regarding unique identification became evident.

1. As difficult as it may be, policymakers should agree on the fundamental security criteria required for the unique identification application as early in the process as possible.

2. It should be expected that if very high security is required for the methods and devices that are required to simply count and keep track of warheads and nuclear explosive material, there will be very difficult problems to solve, and they probably will not be solvable as a last minute effort.

3. The best and most effective development programs must have independent peer review as a primary component—a component that will likely cost as much in effort and funds as the actual development.

4. The most effective way to assemble a successful unique identification device development program would be to assemble an international team of specialists. Certainly the Mayak technical negotiations demonstrated that if each side had a hand in the device development (tagging or other device) and thus a thorough understanding of its technical features, debate about how appropriate it is for an application can proceed very efficiently, and there is less likelihood of bogus objections to occur. The Russian side proposed using a device known as SmartBolt to secure the weapons material containers to be stored at the facility. The development of this device had been funded by the United States under the WSSX activity so both sides were intimately familiar with its technical design, strengths and weaknesses, and it offered good potential for this application.

Finally, it is important to note that in these early days (1998–2002), the use of active, cryptographically-secured tags or seals was not pursued with any diligence. One of the reasons for this was that electronics miniaturization and the general state of development of very small microprocessors was not nearly as advanced as it is today. It is generally assumed that active tags and seals (that is, powered devices) now can be developed that offer the promise of very high security as compared to the passive physical characteristic methods researched by the TAGLAG.

## Nuclear Archaeology

In 1993 Steve Fetter defined nuclear archaeology as a set of methods for examining facilities on a cooperative basis to determine past nuclear material production or processing history, including type, quantity, timing and other relevant attributes, for the purpose of seeking estimates of these attributes that are as independent as possible of operator declarations.[282] This concept garnered particular interest and resulted in a U.S. Department of Energy nuclear laboratory research effort that still is underway today.[283]

A nuclear archaeology program was established at the Pacific Northwest National Laboratory (PNNL) in 1993 and has remained active for some twenty years.[284] PNNL was chosen to conduct the activity due to its co-location with the nine Hanford plutonium production reactors and its longstanding experience with environmental sampling and monitoring. A summary of major accomplishments during this time is provided in Table 7.1.

The momentum for this longstanding effort came from a highly successful initial measurement program to test the validity of the PNNL-developed graphite isotope ratio method (GIRM). It proved too costly to open and sample moderator graphite from any of the Hanford reactors, though proof-of-principle analyses using both Hanford C-reactor and French G-2 reactor reference materials showed good promise.


**Figure 7.2. Workers taking graphite samples from the Hanford C reactor in 1994, in an early effort to test a nuclear archaeology technique.** A full-scale exercise was later carried out in a British Magnox reactor in Wales, and irradiated graphite-samples were analyzed from U.S., Russian, and French reactors. *Source: Jim Fuller and U.S. Department of Energy.*

The arrangements and costs to sample the moderator material from the UK Trawsfyndd-II commercial Magnox reactor were much better, owing in part to the fact that standard operating reactor surveillance methods and tools could be utilized. In a blind test, agreement between the actual operating history (plutonium production) and that inferred using the GIRM approach was accurate to a percent (3.633 tons as declared by the operator versus 3.63 tons predicted).[285] According to PNNL, since the time of this early success, the technique has been improved. It is now applicable to more modern reactor designs by using metallic samples, and the analytical chemistry techniques have been refined.

The GIRM method has been developed and widely published primarily on an unclassified basis—a fundamental requirement for a verification technique best fielded on a cooperative basis between states or between an inspectorate and a host. Additionally, the method can be deployed based on isotopes of several different elements, making it broadly applicable to various reactor types. The use of multiple indicator elements adds redundancy to any measurement campaign, greatly reducing error. Finally, the isotope ratios found to be most useful are generally stable and long-lived, making the "signal" as PNNL calls it, a permanent one, instead of one that decreases over time.

| Date | Activity |
|---|---|
| 1993 | PNNL feasibility project established, Isotope Ratio Method (IRM) for graphite reactors first considered |
| 1993 | Simulation studies at PNNL show promising prospective accuracy |
| 1994 | First elemental characterization studies on PNNL graphite archives |
| 1994 | Proof of principle for Graphite Isotope Ratio Method (GIRM) demonstrated with U.S. Hanford C-reactor and French G2 irradiated reactor graphites |
| 1994 | Thermal Ionization Mass Spectrometry (TIMS) methods developed and employed for titanium and calcium as indicator elements |
| 1995-96 | Full scale demonstration of GIRM at UK Trawsfyndd-II commercial Magnox reactor |
| 1997 | Efforts to extend GIRM application to low-fluence reactors |
| 1998 | Secondary Ionization Mass Spectrometry (SIMS) methods developed to use boron as an indicator element for low fluence applications |
| 1999 | TIMS methods developed to use uranium and plutonium as indicator elements primarily for low fluence applications |
| 2000 | Proof of principle demonstration at UK BEPO reactor for low fluence applications of GIRM |
| 2001 | Development of GIRM specific graphite sample acquisition equipment |
| 2002 | Establishment of UK based graphite sampling team and equipment |
| 2002 | Method development begins for extension of Isotope Ratio Methods to other reactors, such as research reactors |
| 2003 | Development of SIMS capability to assess indicator elements chlorine, titanium and boron as well as TIMS for uranium and plutonium in activated metals |
| 2004 | Proof of principle demonstration for IRM application to the University of Michigan's Ford Research Reactor (shut-down in 2003) |
| 2005-06 | Proof of principle demonstration for IRM application to Russian designed research reactor (Tbilisi, Georgia) |

**Table 7.1. Some nuclear archaeology accomplishments since 1993.**

PNNL researchers suggest that the result is a currently operational nuclear archaeology capability with expected standard errors of less than 2% for well-characterized graphite production reactors. This is certainly better than either current official U.S. or unofficial Russian plutonium production estimates.

While significant progress has been demonstrated for independently determining plutonium production in graphite-moderated reactors by the research team at PNNL, there has neither been any deployment of this capability or any serious joint development effort with another nuclear weapon state. The latter would be a viable next step.

With regards to HEU production, PNNL reports that analyses of enrichment plant operating records appear likely to provide highly accurate estimates, assuming that such records exist and are made available in good faith. At this time, it is not clear to the PNNL research team whether nuclear archaeological techniques could provide significant improvement over records analysis in quantifying HEU production. However, the potential is deemed to be good, based on some initial assessments, to help confirm the authenticity of records-based declarations. Further assessment and demonstration of the applicability of nuclear archaeological techniques to the production of highly-enriched uranium is needed.

## Conclusions

Considerable research and development in the areas of cooperatively monitoring warheads and their dismantlement and in confirming plutonium production histories has already been accomplished. Some of the U.S. investigators involved in this work would argue, as a lesson learned, that successful development of effective verification procedures, technologies, and methods involving nuclear explosive devices and materials will be successful only as a result of collaborative R&D efforts with other states.

Some critical issues remain with regard to protecting sensitive nuclear information, developing very high security tags and seals for uniquely identifying nuclear warheads and components, and for independently determining historical HEU production.

Good models to conduct future work in all these areas are available. Clearly the most effective way to make lasting progress is on a bilateral or multilateral basis between nuclear weapon states as well as with non-nuclear weapon states.

Finally, there needs to be a modern assessment of what nuclear warhead information really needs to be classified considering the fact too much secrecy will certainly hinder verification cooperation.

# Appendix Fissile Materials and Nuclear Weapons

Fissile materials are essential in all nuclear weapons, from simple first-generation bombs, such as those that destroyed Hiroshima and Nagasaki more than sixty years ago, to the lighter, smaller, and much more powerful thermonuclear weapons in arsenals today. The most common fissile materials in use are uranium highly enriched in the isotope uranium-235 (HEU) and plutonium. This Appendix describes briefly the key properties of these fissile materials, how they are used in nuclear weapons, and how they are produced.

## Explosive Fission Chain Reaction

Fissile materials can sustain an explosive fission chain reaction. When the nucleus of a fissile atom absorbs a neutron, it will usually split into two smaller nuclei. In addition to these "fission products," each fission releases two to three neutrons that can cause additional fissions, leading to a chain reaction in a "critical mass" of fissile material (see Figure A.1). The fission of a single nucleus releases one hundred million times more energy per atom than a typical chemical reaction. A large number of such fissions occurring over a short period of time, in a small volume, results in an explosion. About one kilogram of fissile material—the amount fissioned in both the Hiroshima and Nagasaki bombs—releases an energy equivalent to the explosion of about 18 thousand tons (18 kilotons) of chemical high explosives.

The minimum amount of material needed for a chain reaction is defined as the critical mass of the fissile material. A "subcritical" mass will not sustain a chain reaction, because too large a fraction of the neutrons escape from the surface rather than being absorbed by fissile nuclei. The amount of material required to constitute a critical mass can vary widely—depending on the fissile material, its chemical form, and the characteristics of the surrounding materials that can reflect neutrons back into the core. Along with the most common fissile materials, uranium-235 and plutonium-239, the isotopes uranium-233, neptunium-237, and americium-241 are able to sustain a chain reaction.

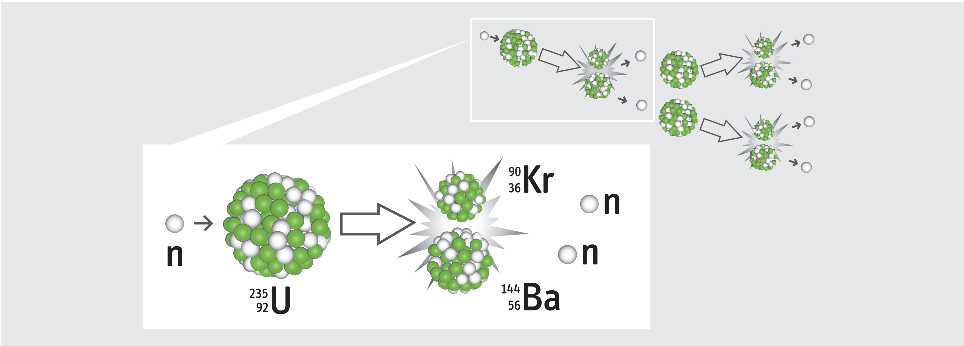


**Figure A.1. An explosive fission chain-reaction releases enormous amounts of energy in one-millionth of a second.** In this example, a neutron is absorbed by the nucleus of uranium-235 (U-235), which splits into two fission products (barium and krypton). The energy set free is carried mainly by the fission products, which separate at high velocities. Additional neutrons are released in the process, which can set off a chain reaction in a critical mass of fissile materials. The chain reaction proceeds extremely fast; there can be 80 doublings of the neutron population in a millionth of a second, fissioning one kilogram of material and releasing an energy equivalent to 18,000 tons of high explosive (TNT).

## Nuclear Weapons

Nuclear weapons are either pure fission explosives, such as the Hiroshima and Nagasaki bombs, or two-stage thermonuclear weapons with a fission explosive as the first stage. The Hiroshima bomb contained about 60 kilograms of uranium enriched to about 80 percent in chain-reacting uranium-235. This was a "gun-type" device in which one subcritical piece of HEU was fired into another to make a super-critical mass (Figure A.2, left). Gun-type weapons are simple devices and have been built and stockpiled without a nuclear explosive test. The U.S. Department of Energy has warned that it might even be possible for intruders in a fissile-materials storage facility to use nuclear materials for onsite assembly of an improvised nuclear explosive device (IND) in the short time before guards could intervene.

The Nagasaki bomb operated using implosion, which has been incorporated into most modern weapons. Chemical explosives compress a subcritical mass of material into a high-density spherical mass. The compression reduces the spaces between the atomic nuclei and results in less leakage of neutrons out of the mass, with the result that it becomes super-critical (Figure A.2, right).

For either design, the maximum yield is achieved when the chain reaction is initiated in the fissile mass at the moment when it will grow most rapidly, i.e., when the mass is most super-critical. HEU can be used in either gun-type or implosion weapons. As is explained below, plutonium cannot be used in a gun-type device to achieve a high-yield fission explosion.

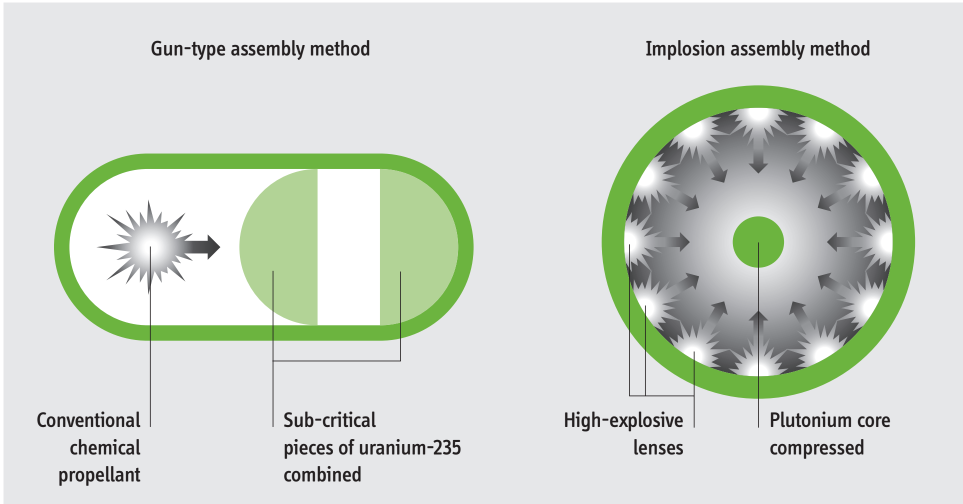


**Figure A.2. Alternative methods for creating a supercritical mass in a nuclear weapon.** In the technically less sophisticated "gun-type" method used in the Hiroshima bomb (left), a subcritical projectile of HEU is propelled towards a subcritical target of HEU. This assembly process is relatively slow. For plutonium, the faster "implosion" method used in the Nagasaki bomb is required. This involves compression of a mass of fissile material. Much less material is needed for the implosion method because the fissile material is compressed beyond its normal metallic density. For an increase in density by a factor of two, the critical mass is reduced to one quarter of its normal-density value.

Because both implosion and neutron-reflecting material around it can transform a subcritical into a supercritical mass, the actual amounts of fissile material in the pits of modern implosion-type nuclear weapons are considerably smaller than a bare or unreflected critical mass. Experts advising the IAEA have estimated "significant quantities" of fissile material, defined to be the amount required to make a first-generation implosion bomb of the Nagasaki-type (see Figure A.2, right), including production losses. The significant quantities are 8 kg for plutonium and 25 kg of uranum-235 contained in HEU, including losses during production. The Nagasaki bomb contained 6 kg of plutonium, of which about 1 kg fissioned. A similar uranium-based first generation implosion weapon could contain about 20 kg of HEU (enriched to 90% uranium-235, i.e. 18 kg of uranium-235 in HEU).

The United States has declassified the fact that 4 kg of plutonium is sufficient to make a more modern nuclear explosive device. As the IAEA significant quantities recognize, an implosion fission weapon requires about three times as much fissile material if it is based on HEU rather than plutonium. This suggests a modern HEU fission weapon could contain only about 12 kg of HEU.

In modern nuclear weapons, the yield of the fission explosion is typically "boosted" by a factor of about ten by introducing a mixed gas of two heavy isotopes of hydrogen, deuterium and tritium, into a hollow shell of fissile material (the "pit") just before it is imploded. When the temperature of the fissioning material inside the pit reaches about 100 million degrees, it ignites the fusion of tritium with deuterium, which produces a burst of neutrons that increases the fraction of fissile material fissioned and thereby the power of the explosion.

In a thermonuclear weapon, the nuclear explosion of a fission "primary" generates X-rays that compress and ignite a "secondary" containing thermonuclear fuel, where much of the energy is created by the fusion of the light nuclei, deuterium and tritium. The tritium in the secondary is made during the explosion by neutrons splitting lithium-6 into tritium and helium.

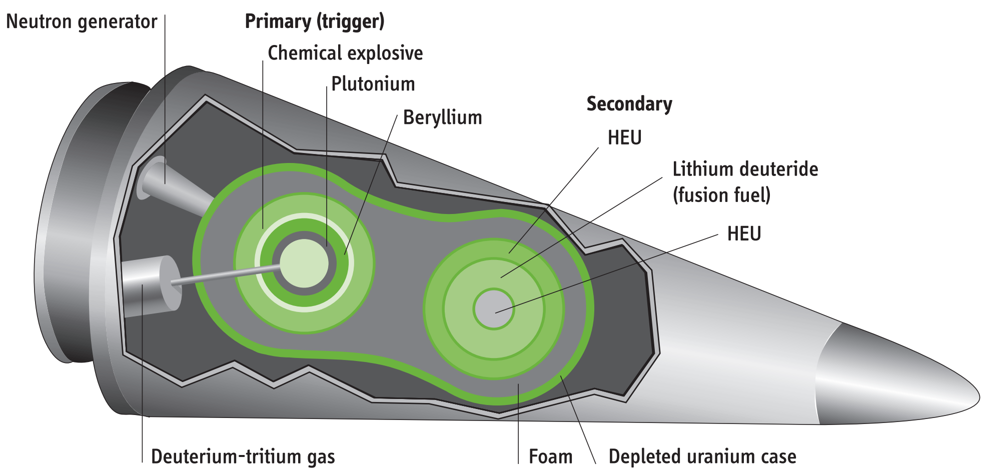


**Figure A.3. A modern thermonuclear weapon usually contains both plutonium and highly enriched uranium.** Typically, these warheads have a mass of about 200 – 300 kg and a yield of hundreds of kilotons of chemical explosive, which corresponds to about one kilogram per kiloton of explosive yield. For comparison, the nuclear weapons that destroyed Hiroshima and Nagasaki weighed 300 kg per kiloton. Source: Adapted from Report of the Select Committee on U.S. National Security and Military/Commercial Concerns with the People's Republic of China, U.S. House of Representatives, Washington, DC, 1999. See Volume I, Chapter 2, "PRC Theft of U.S. Thermonuclear Warhead Design Information," p. 78.

Modern nuclear weapons generally contain both plutonium and HEU (Figure A.3). The primary fission stage of a thermonuclear weapon can contain either plutonium or HEU or both (the last is known as a composite core or pit). HEU also is often added to the secondary stage as a 'spark-plug' to generate neutrons from a fission chain reaction to begin the conversion of the lithium-6 to tritium and to increase its yield. Natural or depleted uranium is also used in the outer radiation case, which confines the X-rays from the primary while they compress the thermonuclear secondary. Neutrons from thermonuclear reaction also induce fission in the uranium, which can contribute one-half of the energy yield of the secondary.

A rough estimate of average plutonium and HEU in deployed thermonuclear weapons can be obtained by dividing the estimated total stocks of weapon fissile materials possessed by Russia and the United States at the end of the Cold War by the numbers of nuclear weapons that each deployed during the 1980s: about 4 kg of plutonium and 25 kg of HEU. Many of the older U.S. and Russian strategic weapons had yields in excess of 1 MT and may have contained more than 25 kg HEU. The lower yield thermonuclear weapons deployed today (typically around 100–500 kt) could contain 10–20 kg of HEU.

| | Plutonium | HEU | Yield | Example |
|---|---|---|---|---|
| IAEA Significant Quantity (SQ) | 8 kg | 25 kg* | | |
| 1st-generation gun-type weapon | n/a | 50 – 60 kg | 20 kt | Hiroshima |
| 1st-generation implosion-type weapon | 5 – 6 kg | 15 – 18 kg | 20 kt | Nagasaki (6 kg Pu) |
| 2nd-generation single-stage weapon | 4 – 5 kg | 12 kg | 40 – 80 kt | (levitated or boosted pit) |
| Two-stage low-yield weapon | 3 – 4 kg Pu and 4 – 7 kg HEU | | 100 – 160 kt | W76 |
| Two-stage medium-yield weapon | 3 – 4 kg Pu and 15 – 25 kg HEU | | 300 – 500 kt | W87/W88 |
| Two-stage high-yield weapon | 3 – 4 kg Pu and 50+ kg HEU | | 1 – 10 MT | B83 |

**Table A.1. Nuclear weapon generations and estimated respective fissile material quantities.** Warhead types are U.S. warhead-designations. The estimates assume about 18 kt per kilogram of nuclear material fissioned, a fission-fraction of 50% for a 2nd-generation and two-stage weapon, and a yield fraction of 50% in the secondary from fission in the two-stage weapon. *The significant quantity specifies uranium-235 contained in highly enriched uranium.

## Production of Fissile Materials

Fissile materials that can be directly used in a nuclear weapon do not occur in nature. They must be produced through complex physical and chemical processes. The difficulties associated with producing these materials remains the main technical barrier to the acquisition of nuclear weapons.

***Highly enriched uranium (HEU).*** In nature, uranium-235 makes up only 0.7 percent of natural uranium. The remainder is almost entirely non-chain-reacting uranium-238. Although an infinite mass of uranium with a uranium-235 enrichment of 6 percent could, in principle, sustain an explosive chain reaction, weapons experts have advised the IAEA that uranium enriched to above 20 percent uranium-235 is required to make a fission weapon of practical size. The IAEA therefore considers uranium enriched to 20 per cent or above "direct use" weapon-material and defines it as highly enriched uranium. To minimize their masses, however, actual weapons typically use uranium enriched to 90-percent uranium-235 or higher. Such uranium is sometimes defined as "weapon-grade."

The isotopes uranium-235 and uranium-238 are chemically virtually identical and differ in weight by only one percent. To produce uranium enriched in uranium-235 therefore requires sophisticated isotope separation technology. The ability to do so on a scale sufficient to make nuclear weapons or enough low-enriched fuel to sustain a large power reactor is found in only a relatively small number of nations.

In a uranium enrichment facility, the process splits the feed (usually natural uranium) into two streams: a product stream enriched in uranium-235, and a waste (or "tails") stream depleted in uranium-235.

All countries that have built new enrichment plants during the past three decades have chosen centrifuge technology. Gas centrifuges spin uranium hexafluoride (UF6) gas at enormous speeds, so that the uranium is pressed against the wall with more than 100,000 times the force of gravity. The molecules containing the heavier uranium-238 atoms concentrate slightly more toward the wall relative to the molecules containing the lighter uranium-235. An axial circulation of the UF6 is induced within the centrifuge, which multiplies this separation along the length of the centrifuge, and increases the overall efficiency of the machine significantly (see Figure A.4 for an illustration).

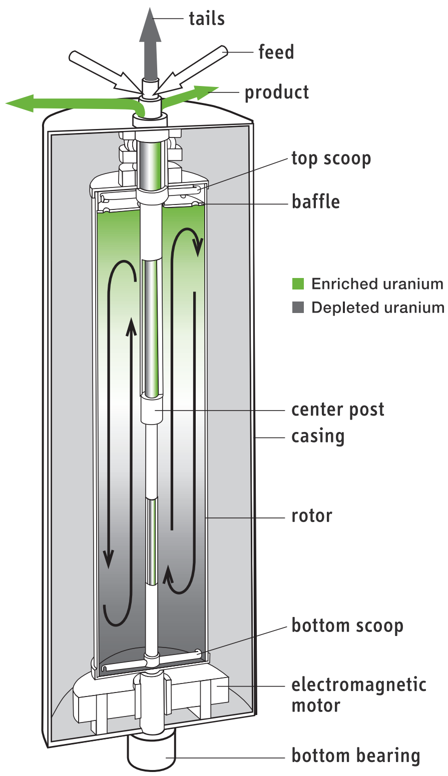


**Figure A.4. The gas centrifuge for uranium enrichment.** The possibility of using centrifuges to separate isotopes was raised shortly after isotopes were discovered in 1919. The first experiments using centrifuges to separate isotopes of uranium (and other elements) were successfully carried out on a small scale prior to and during World War II, but the technology only became economically competitive in the 1970s. Today, centrifuges are the most economic enrichment technology, but also the most proliferation-prone.

Gaseous diffusion enrichment, invented during the Manhattan Project, exploits the fact that, in a uranium-containing gas, the lighter molecules containing uranium-235 move more quickly through the pores in a barrier than those containing uranium-238. The effect is only a few tenths of a percent, however, and the molecules have to be pumped through thousands of barriers before HEU is produced.

A third enrichment method, electromagnetic separation, involves introducing a beam of uranium-containing ions into a magnetic field and separating it into two beams by virtue of the fact that the path of the electrically charged ions containing the heavier uranium-238 atoms is bent less by the magnetic field. This method of enrichment was used by the United States during the World War II Manhattan Project and attempted by Iraq in the late 1980s. It is no longer in use.

***Plutonium.*** Plutonium is an artificial isotope produced in nuclear reactors after uranium-238 absorbs a neutron creating uranium-239. The uranium-239 subsequently decays to plutonium-239 via the intermediate short-lived isotope neptunium-239.

The longer an atom of plutonium-239 stays in a reactor after it has been created, the greater the likelihood that it will absorb a second neutron and fission or become plutonium-240—or absorb a third or fourth neutron and become plutonium-241 or plutonium-242. Plutonium therefore comes in a variety of isotopic mixtures.

The plutonium in typical power-reactor spent fuel (reactor-grade plutonium) contains 50–60% plutonium-239, and about 25% plutonium-240. Weapon designers prefer to work with a mixture that is as rich in plutonium-239 as feasible, because of its relatively low rate of generation of radioactive heat and relatively low spontaneous emissions of neutrons and gamma rays (Table A.2). Weapon-grade plutonium contains more than 90% of the isotope plutonium-239 and has a critical mass about three-quarters that of reactor-grade plutonium.

| Isotope | Bare Critical Mass [kg] | Half Life [years] | Decay Heat [watts/kg] | Neutron Generation [neutrons/g-sec] |
|---|---|---|---|---|
| Pu-238 | 10 | 88 | 560 | 2600 |
| Pu-239 | 10 | 24,000 | 1.9 | 0.02 |
| Pu-240 | 40 | 6,600 | 6.8 | 900 |
| Pu-241 | 13 | 14 | 4.2 | 0.05 |
| Pu-242 | 80 | 380,000 | 0.1 | 1700 |
| Am-241 | 60 | 430 | 110 | 1.2 |
| WPu (94% Pu-239) | 10.7 | | 2.3 | 50 |
| RPu (55% Pu-239) | 14.4 | | 20 | 460 |

**Table A.2. Key properties of plutonium isotopes and Am-241 into which Pu-241 decays.** Data from: U.S. Department of Energy, “Annex: Attributes of Proliferation Resistance for Civilian Nuclear Power Systems,” in *Technological Opportunities to Increase the Proliferation Resistance of Global Nuclear Power Systems*, TOPS, Washington, DC, U.S. Department of Energy, Nuclear Energy Research Advisory Committee, 2000, www.ipfmlibrary.org/doe00b.pdf, p. 4; see also, J. Kang et al., “Limited Proliferation-Resistance Benefits from Recycling Unseparated Transuranics and Lanthanides from Light-Water Reactor Spent Fuel,” *Science & Global Security*, Vol. 13, 2005, p. 169. WPu is typical weapon-grade plutonium, and RPu is typical reactor-grade plutonium.

For a time, many in the nuclear industry thought that the plutonium generated in power reactors could not be used for weapons. It was believed that the large fraction of plutonium-240 in reactor-grade plutonium would reduce the explosive yield of a weapon to insignificance. Plutonium-240 fissions spontaneously, emitting neutrons. This increases the probability that a neutron would initiate a chain reaction before the bomb assembly reached its maximum supercritical state. This probability increases with the percentage of plutonium-240.

For gun-type designs, such “pre-detonation” reduces the yield a thousand-fold, even for weapon-grade plutonium. The high neutron-production rate from reactor-grade plutonium similarly reduces the probable yield of a first-generation implosion design—but only about ten-fold, because of the much shorter time for the assembly of a supercritical mass. In a Nagasaki-type design, even the earliest possible pre-initiation of the chain reaction would not reduce the yield below about 1000 tons TNT equivalent. That would still be a devastating weapon.

More modern nuclear weapon designs are insensitive to the isotopic mix in the plutonium. As summarized in a 1997 U.S. Department of Energy report: "Virtually any combination of plutonium isotopes ... can be used to make a nuclear weapon." The report recognizes that "not all combinations, however, are equally convenient or efficient," but concludes that "reactor-grade plutonium is weapons-usable, whether by unsophisticated proliferators or by advanced nuclear weapon states." [286]

For use in a nuclear weapon, the plutonium must be separated from the irradiated uranium and the highly radioactive fission products that it contains. Separation of the plutonium is done in a chemical "reprocessing" operation, behind heavy shielding and with remote handling. Reprocessing requires both resources and technical expertise. Detailed descriptions of the process have been available in the published technical literature, however, since the "Atoms for Peace" Conferences of the 1950s and 60s.

Spent fuel can only be handled remotely, due to the very intense radiation field. This makes its diversion or theft a rather unrealistic scenario. Separated plutonium can be handled without radiation shielding, but is dangerous when inhaled or ingested.

# Endnotes

## Chapter 1. Nuclear Weapon and Fissile Material Stockpiles and Production

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102. For the history and operating experience of THORP, see Martin Forwood, *The Legacy of Reprocessing in the United Kingdom,* IPFM Research Report Number 5, July 2008, fissilematerials.org/library/rr05.pdf.

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116. *Ibid.*

117. *Ibid.* Action 19: "All States agree on the importance of supporting cooperation among Governments, the United Nations, other international and regional organizations and civil society aimed at

increasing confidence, improving transparency and developing efficient verification capabilities related to nuclear disarmament." Action 20: "States parties should submit regular reports, within the framework of the strengthened review process for the Treaty, on the implementation of the present action plan ..." Action 21: "As a confidence-building measure, all the nuclear weapon states are encouraged to agree as soon as possible on a standard reporting form and to determine appropriate reporting intervals for the purpose of voluntarily providing standard information."

118. *Ibid,* Action 5: "The nuclear weapon states commit to accelerate concrete progress on the steps leading to nuclear disarmament... [and] are called upon to report ... to the Preparatory Committee at 2014."

119. This proposal included reporting by the NPT weapon states on: the extent of their reductions in nuclear stockpiles; number of reduced nuclear warheads and delivery systems; number of dismantled nuclear warheads and delivery systems, as well as the pace of dismantlement, including the types of dismantled nuclear warheads and delivery systems; aggregate number of nuclear warheads and delivery systems and/or those deployed; years in which their production of fissile material for nuclear weapons had ceased; amount of fissile material declared excess to and removed from nuclear explosive purposes or national security requirements, and plans for its disposition; and plans or intentions for further nuclear disarmament measures. *Working Paper submitted by Japan*, 2008 NPT Preparatory Committee, NPT/CONF.2010/PC.II/WP.10, 28 April 2008.

120. The categories included: nuclear doctrine; fissile material policy on production and control; warhead and delivery vehicle numbers; and strategic and tactical nuclear weapon reductions. Working paper submitted by Australia and New Zealand, 2010 NPT Review Conference, NPT/CONF.20I0/WP.40, 22 April 2010.

121. "Statement of the Third Ministerial Meeting of the Non-Proliferation and Disarmament Initiative," New York, 21 September 2011, www.foreignminister.gov.au/releases/2011/kr_mr_110921a.html. NPDI members are Australia, Canada, Chile, Germany, Japan, Mexico, the Netherlands, Poland, Turkey, and the United Arab Emirates.

122. "Transparency of nuclear weapons: the Non-Proliferation and Disarmament Initiative," Working paper submitted by Australia, Canada, Chile, Germany, Japan, Mexico, the Netherlands, Poland, Turkey and the United Arab Emirates, 2012 NPT Prepcom, NPT/CONF.2015/PC.I/WP.12, 20 April 2012.

123. *Repository of Information Provided by Nuclear weapon states,* United Nations Office of Disarmament Affairs, www.un.org/disarmament/WMD/Nuclear/Repository.

124. "First P5 Follow-up Meeting to the NPT Review Conference," France's Ministry of Foreign and European Affairs, Paris, 1 July 2011, www.franceonu.org/spip.php?article5660.

125. "Third P5 Conference: Implementing the NPT," Washington, DC, 29 June 2012, www.state.gov/r/pa/prs/ps/2012/06/194292.htm.

126. *The Structure and Content of Agreements between the Agency and States Required in Connection with the Treaty on the Non-proliferation of Nuclear Weapons* (IAEA, INFCIRC/153, corrected) paragraph 57, International Atomic Energy Agency, June 1972, www.iaea.org/Publications/Documents/Infcircs/Others/infcirc153.pdf.

127. *Ibid,* Paragraph 7.

128. The nuclear weapon states outside the NPT are Israel, India, Pakistan and North Korea. All of these states have expressed support in principle for the goal of global nuclear disarmament. See *Reducing and Eliminating Nuclear Weapons: Country Perspectives on the Challenges to Nuclear Disarmament,* www.ipfmlibrary.org/gfmr09cv.pdf.

129. *2010 NPT Review Conference Final Document,* Action 3, p. 20.

130. Paragraph 94, p. 14. *op. cit.*

131. See e.g. the *Nuclear Weapons Databooks* for the U.S., the United Kingdom, Soviet Union, France, and China published by the Natural Resources Defense Council, Washington, DC. Updated estimates on nuclear warhead numbers are provided by the Federation of American Scientists in "Nuclear Notebook" articles published by the *Bulletin of Atomic Scientists*. Estimates of stockpiles and production of fissile materials have been provided since 2006 by IPFM in its annual *Global Fissile Material Report*.

132. At their June 2012 meeting, the weapon states agreed on "a P5 working group led by China, assigned to develop a glossary of definitions for key nuclear terms." See "Third P5 Conference: Implementing the NPT," Washington DC, 29 June 2012, www.state.gov/r/pa/prs/ps/2012/06/194292.htm. Some of the technical issues and the need for agreed definitions are discussed in *Monitoring Nuclear Weapons and Nuclear-Explosive Materials: An Assessment of Methods and Capabilities,* U.S. National Academy of Sciences, Washington, DC, 2005.

133. An example of a set of agreed definitions can be found in Protocol 1 of the 2010 Treaty between the United States of America and the Russian Federation on Measures for the Further Reduction and Limitation of Strategic Offensive Arms (New START Treaty), www.state.gov/documents/organization/140047.pdf.

134. A more detailed analysis of the adoption of New START reporting rules by all the weapon states, including detailed country studies and model New START declarations, can be found in Tamara Patton, Pavel Podvig and Phillip Schell, *A New START Model for Transparency in Nuclear Disarmament,* UNIDIR, 2013, www.unidir.org/files/publications/pdfs/a-new-start-model-for-transparency-in-nuclear-disarmament-en-409.pdf.

135. *Final Document of the 1995 Nonproliferation Treaty Review Conference,* Part I. Decision 2, Principles and objectives for nuclear non-proliferation and disarmament, 4c, www.un.org/depts/ddar/nptconf/2142.htm.

136. *Highly Enriched Uranium: Striking a Balance.op. cit.,* updated in *Highly Enriched Uranium Inventory: Amounts of Highly Enriched Uranium in the United States, op. cit. Plutonium: The First 50 Years,* updated in *The United States Plutonium Balance, 1944–2009.*

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139. *Communications Received from Certain Member States Concerning their Policies Regarding the Management of Plutonium,* INFCIRC/549, International Atomic Energy Agency. Documents available at www.iaea.org/Publications/Documents/Infcircs.

140. This includes HEU that has been shipped for downblending, as of December 2012.

141. The Plutonium Management Disposition Agreement, signed in 2000 and amended in 2010, commits the United States and Russia each to dispose of 34 tons of excess plutonium starting in 2018. The text is available at fissilematerials.org/library/PMDA2010.pdf.

142. Written reply to a Parliamentary question from Paul Flynn, MP, on 21 January 2013, Hansard reference Column 70W, www.publications.parliament.uk/pa/cm201213/cmhansrd/cm130121/

text/130121w0004.htm. This is cited in UK Ministry of Defense letter to Rob Edwards, 25 July 2013, robedwards.typepad.com/files/mod-foi-response-on-dismantling-nuclear-weapons.pdf.

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149. Rob Edwards, "UK's Nuclear Weapons Being Dismantled Under Disarmament Obligations," *op. cit.,* and "Three of Britain's nuclear warheads are being dismantled every year" and UK Ministry of Defence statement of 25 July 2013.

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## Chapter 6. The International Plutonium Guidelines

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256. Article 12(a)(5) provides that the IAEA has "the right to require deposit with the Agency of any excess of any fissionable materials recovered or produced as a byproduct over what is needed in order to prevent stockpiling of these materials." It also provides that, "At the request of the member or members concerned, special fissionable materials so deposited with the Agency shall be returned promptly to the member or members concerned, provided that the material is used for peaceful purposes under continuing IAEA safeguards."

257. For insight into the origins of the guidelines, see the remarks of Jim Finucane, at the conference "Civil Separated Plutonium Stocks: Planning for the Future," Institute for Science and International Security, Washington, DC, 14 March 2000, www.isis-online.org/publications/civil_pu_conference/index.html.

258. The IAEA, however, provided the venue for the nine-nation meetings and has published the guidelines and annual declarations. By contrast, the IAEA had a formal and substantive role in the IPS discussions, providing a secretariat that drafted numerous papers and proposals for discussions by experts from participating member states.

259. Certain categories of plutonium were excluded from the guidelines: plutonium-238; plutonium used in gram quantities or as a sensing component in instruments; and plutonium that has been exempted from safeguards or is in such diluted form that otherwise-applicable IAEA safeguards do not apply or have been terminated.

260. *Guidelines for the Management of Plutonium,* 1998, Paragraph 3.

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262. Some of these conditions on retransfers of plutonium have their basis in the European Community's adopted "Declaration of Common Policy" published in 1984 as INFCIRC/322.

263. As a result of the Fukushima nuclear disaster in March 2011, there is a national debate in Japan to reassess the future of its nuclear program, including its reprocessing program.

264. The Institute for Science and International Security (Washington, DC) periodically reviews the implementation of the Guidelines. See isis-online.org/studies/category/global-stocks-of-nuclear-explosive-material.

265. Sweden shipped its 3 kg of separated plutonium to the United States for disposal in 2012, "Fact Sheet: Plutonium Removal from Sweden," The White House, 26 March 2012, www.whitehouse.gov/the-press-office/2012/03/26/fact-sheet-plutonium-removal-sweden.

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270. France and the United Kingdom also have submitted their civil nuclear materials to EURATOM safeguards.

271. France and the United Kingdom have placed all civil nuclear facilities under EURATOM safeguards with no national security exclusion.

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[277] See for example *Fissile Material Transparency Technology Demonstration,* Los Alamos National Laboratory, LA-UR-00-2239, August 2000, www.lanl.gov/orgs/n/n1/FMTTD/index_main.htm. There does not seem to be any Russian, U.S, or NGO compendium of these joint demonstrations. The several joint workshop handouts cannot be referenced.

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# International Panel on Fissile Materials: Members

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Kræmk Visuell

Over the past six decades, our understanding of the nuclear danger has expanded from the threat posed by the vast nuclear arsenals created by the superpowers in the Cold War to encompass the proliferation of nuclear weapons to additional states and now also to terrorist groups. To reduce this danger, it is essential to secure and to sharply reduce all stocks of highly enriched uranium and separated plutonium, the key materials in nuclear weapons, and to limit any further production. Achieving these goals will require increased transparency especially by nuclear weapon states about their nuclear weapon and fissile material stockpiles and production histories. These measures also would be an important step on the path to achieving and sustaining a world free of nuclear weapons.

The mission of the IPFM is to advance the technical basis for cooperative international policy initiatives to achieve these goals.

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