IPFM
INTERNATIONAL PANEL
ON FISSILE MATERIALS

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Increasing Transparency

of Nuclear-warhead and Fissile-material Stocks as a Step toward Disarmament

Proposals for the NPT PrepCom, Geneva, 24 April 2013

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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 seventeen 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 about 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 27 members include nuclear experts from Brazil, China, France, Germany, India, Iran, Japan, South Korea, Mexico, the Netherlands, Norway, Pakistan, Russia, South Africa, Sweden, the United Kingdom, and the United States. Short biographies of the panel members can be found on the IPFM website, www.fissilematerials.org.

IPFM research and reports are shared with international organizations, national governments and nongovernmental groups. The reports are available on the IPFM website and through the IPFM blog, www.fissilematerials.org/blog.

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An earlier version of these proposals was presented in Vienna at the April-May 2012 nuclear Non-Proliferation Treaty (NPT) Preparatory Committee.

Introduction

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."[1] 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."[2]

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.[3] 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.[4]

In this report, the International Panel on Fissile Materials (IPFM) lays out a set of options for how NPT nuclear-weapon states could fulfill their transparency commitments through a series of successively more detailed public declarations of the numbers and deployment status of their nuclear warheads and of their inventories, production, and disposition histories of highly enriched uranium (HEU) and plutonium, the key ingredients in nuclear weapons. A more extensive study will be published later in 2013 as IPFM's *Global Fissile Material Report 2012-2013*.

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.[5] At the 2010 Review Conference, Australia and New Zealand also proposed reporting categories.[6]

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."[7] In April 2012, NPDI presented a model reporting form that weapon states could consider.[8] 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."[9]

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."[10] 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."[11]

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.[12] 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.[13] 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.[14]

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."[15] 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."[16]

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.[17]

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.[18] 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.[19] 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

In 2012, the global stockpile of nuclear weapons was estimated at over 19,000 weapons, with the United States and Russia together holding over 18,000 of these weapons and the other seven nuclear-weapon states holding a combined total of about 1000 weapons.

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 1) would provide an initial snapshot of the state of the arsenal of each NPT weapon state.

Possible reporting form to fill in

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 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." In modern nuclear weapons, tritium is used to boost the yield of the fission explosion. It has a half-life of about 12 years and is replaced on a regular basis.

Most NPT weapon states have already made public some data relating to their nuclear arsenals. In 2010, the United States released at the NPT Review Conference the exact number of its operational warheads as of 30 September 2009 and declared less precisely that, in addition, it had "several thousand" retired warheads awaiting dismantlement.[20] It also made public that, as of June 2010, it had about 14,000 excess and reserve plutonium pits from dismantled warheads in storage.[21]

Under the bilateral START (1994–2009) and New-START (since 2011) agreements, Russia and the United States have made public some information on their deployed strategic warheads. Twice each year they release information on their total numbers of deployed ICBMs, SLBMs and long-range nuclear bombers, along with the total numbers of nuclear warheads actually deployed on ICBMs and SLBMs and counted as deployed on their bombers (1 each).[22] They share more detailed information on a confidential bilateral basis.[23] The United States publishes this data, Russia does not.

The UK has released some information on the evolution of its nuclear arsenal and delivery systems since 1952 and has declared that it has reduced to fewer than 160 operational nuclear warheads for deployment on its SLBMs and has eliminated its nuclear bombs.[24] The UK also has announced plans to reduce its arsenal to not more than 180 total and 120 operational warheads by the mid-2020s.[25]

France declared in 2005 that it has only about 50 SLBMs and 50 nuclear-capable aircraft (they are equipped with medium-range air-to-surface missiles). It also reported the rough total numbers and the types of these nuclear-weapon delivery systems for 1985 and 1995.[26] In 2008, France announced that it had "dismantled its ground-to-ground nuclear missiles, … reduced the number of its nuclear-powered ballistic missile submarines by a third … [and] with respect to the airborne component, the number of nuclear weapons, missiles and aircraft will be reduced by one-third" and that "after this reduction, … [the] arsenal will include fewer than 300 nuclear warheads. That is half of the maximum number of warheads we had during the Cold War."[27] France also declared that "it has no other weapons beside those in its operational stockpile."[28]

In 2004, China indicated that its warhead stockpile was smaller than those of the other four NPT weapon states, but has not updated this statement.[29]

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.[30] 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.[31]

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.

The United States has made detailed declarations for both its HEU and plutonium stockpiles as of 1996 and 1994 respectively and provided subsequent updates.[32] 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 UK under a military cooperation agreement was kept secret. The UK, in 1998, declared its total fissile material stocks.[33] 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.[34]

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.[35] (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 UK and France (and Germany) also declare stocks of civilian HEU in their INFCIRC/549 declarations.

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.

As of the end of 2012, the global stockpile of HEU is estimated to be about 1380 ± 125 tons, enough for more than 55,000 simple, first generation implosion fission 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 global HEU stockpile has been shrinking. 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. The United States, which has eliminated about141 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.

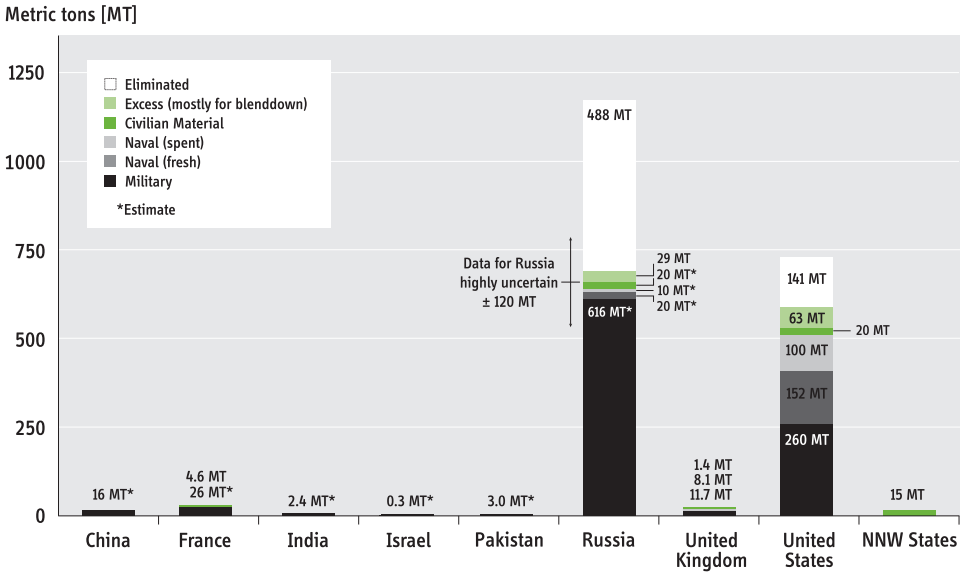

Figure 1. National stocks of highly enriched uranium as of 2012. The numbers for the United Kingdom and United States are based on official publications and statements. The civilian HEU stocks of France and the United Kingdom are based on their public declarations to the IAEA. Numbers with asterisks 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. HEU in non-nuclear weapon (NNW) states is under IAEA safeguards.

The United States, United Kingdom, Russia, France and China have all stopped producing plutonium for weapons. As with HEU, the first four of these states have made official declarations to this effect, but China has done so informally.

The global stockpile of separated plutonium in 2012 was about 490 ± 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 per cent 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.

Israel, India and Pakistan continue to produce plutonium for weapons. North Korea announced in 2013 that it intends to resume production.

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

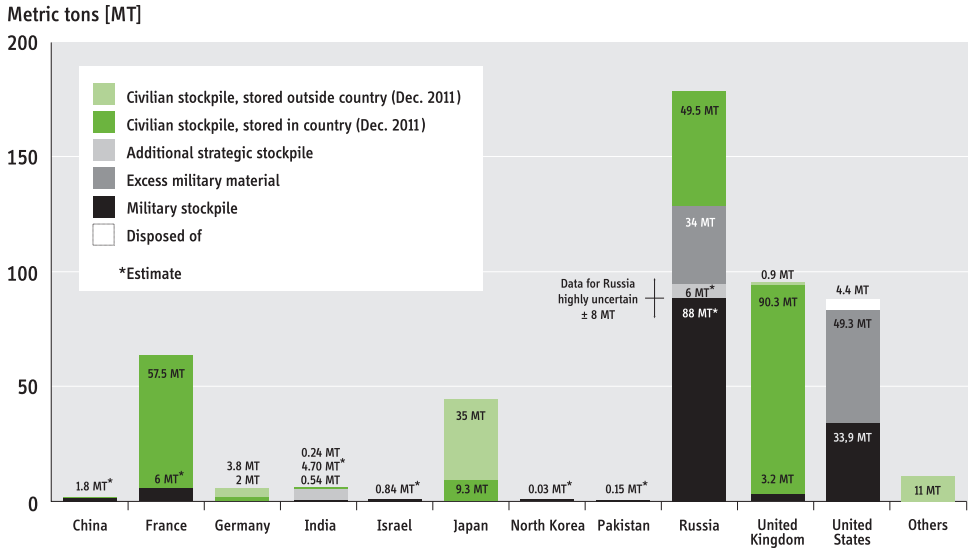

Figure 2. National stocks of separated plutonium as of 2012. Civilian stocks are based on the INFCIRC/549 declarations published in 2012, which report material as of 31 December 2011 and are listed by ownership, not by current location. Weapon stocks are based on IPFM estimates except for the United 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.

As part of their baseline declarations on fissile materials, 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.

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 UK, 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.

Possible reporting form to fill in

	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. 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 practicable 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.[36]

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.[37] None of this excess plutonium has yet been disposed of and, as of the end of 2012, agreement on verification had not been reached.

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.[38]

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.[39]

This use of fissile material is significant because the quantities of HEU reserved for naval reactor fuel are huge. As noted earlier, the United States alone has set aside for naval fuel a stockpile of 152 tons of weapon-grade uranium – enough for more than 6,000 nuclear weapons.[40] In addition to the United States, the UK and Russia operate HEU-fueled naval reactors. France and (we believe) China do not use HEU in their naval fuel.[41]

In the United States over 4 tons of plutonium have been sent to the Waste Isolation Pilot Plant (WIPP) in New Mexico for geological disposal.[42] 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-reduction 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.[43] The UK and France have indicated that significant numbers of warheads that were in their arsenals are no longer operational – but have 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.[44]

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.[45]

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.[46] 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.[47]

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."[48] 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 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.[49] The UK 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.[50] 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.[51] 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 UK, France, and Russia, started to develop and demonstrate nuclear archaeology methods for graphite-moderated production reactors.[52]

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 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.[53] In 2009, France invited observers to visit its enrichment and plutonium production complexes at Pierrelatte and Marcoule, undergoing dismantlement.[54] China has revealed an unfinished underground plutonium production complex ("Project 816") at Fuling in Sichuan Province and opened it up for tourists.[55]

	Graphite Reactors	Heavy Water Reactors
U.S.	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) Seversk: 5 reactors (I-1, IE-2, ADE-3, -4, -5) Zheleznogorsk: 3 reactors (AD, ADE-1, -2)	Mayak 4 reactors (OK-180, -190, -190M, LF-2)
UK	Sellafield (Windscale and Calder Hall): 6 reactors Chapelcross: 4 reactors	n/a
France	Marcoule 3 reactors (G1, G2, G3)	Marcoule 2 Célestin reactors
China	Jiuquan: 1 reactor Guangyuan: 1 reactor	n/a

Table 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.

Endnotes

1. For the "Action Plan on Nuclear Disarmament" see 2010 NPT Review Conference Final Document, Volume 1, New York 2010, pp. 19–21, www.un.org/en/conf/npt/2010.

2. Ibid.

3. 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 ..."* Action Plan on Nuclear Disarmament, 2010 NPT Review Conference.

4. 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."* Action Plan on Nuclear Disarmament, 2010 NPT Review Conference.

5. 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.

6. 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.

7. "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.

8. "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.

9. *Repository of Information Provided by Nuclear-Weapon States,* United Nations Office of Disarmament Affairs, www.un.org/disarmament/WMD/Nuclear/Repository.

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

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

12. *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.

13. INFCIRC/153, paragraph 7.

14. 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.

15. *2010 NPT Review Conference Final Document,* Action 3, p. 20.

16. Paragraph 94, p. 14. op. cit.

17. See e.g. the *Nuclear Weapons Databooks* for the U.S., the UK, 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*.

18. 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", "Third P5 Conference: Implementing the NPT," Washington DC, 29 June 2012. 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.

19. 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.

20. The United States declared 5113 "operational" warheads as of 30 September 2009; see *Increasing Transparency in the U.S. Nuclear Weapons Stockpile,* U.S. Department of Defense Factsheet, 3 May 2010, www.defense.gov/news/d20100503stockpile.pdf.

21. "Plutonium Pit Storage," *PantexInfo,* June 2010. Virtually all U.S. separated plutonium pits are stored at the Pantex nuclear warhead assembly and disassembly plant in Amarillo, Texas, which is the designated national "interim staging site" pending pit disposition.

22. The New-START delivery system and warhead numbers for Russia and the United States as of 1 September 2012 can be found at *New START Treaty Aggregate Numbers of Strategic Offensive Arms,* 30 November 2012, www.fas.org/programs/ssp/nukes/armscontrol/NewSTART_USnumbers090112.pdf.

23. "Protocol to the New-START Treaty", 2010. The additional shared information includes the number of deployed warheads at each ICBM and SLBM base and, during inspections, the number of reentry vehicles on each ICBM and SLBM at the inspected base. They also share diagrams of facilities where inspections may be conducted, the coordinates of ICBM missile silos and missile-basing submarine bases, and ICBM, SLBM and heavy-bomber production, storage, maintenance, loading and elimination sites, along with technical data on the ICBMs, SLBMs and bombers.

24. The UK never deployed land-based nuclear missiles. Strategic Defense Review, presented to the UK Parliament, July 1998; *The Future of the UK's Strategic Nuclear Deterrent: the Strategic Context,* UK House of Commons Defence Committee, 20 June 2006. Also *Securing Britain in an Age of Uncertainty: The Strategic Defence and Security Review,* UK Government, October 2010.

25. "UK statement at the UN Disarmament Conference," 4 April 2012, http://ukun.fco.gov.uk/en/news/?view=PressS&id=751944882.

26. *Fighting Proliferation, Promoting Arms Control and Disarmament: France's Contribution,* Government of France, February 2005, www.diplomatie.gouv.fr/fr/IMG/pdf/maitrise_armement.pdf. According to this official report, in 1985, France had about 125 land-based missiles, about 100 nuclear-capable aircraft and just over 50 SLBMs. In 1995, it had about 50 land-based missiles, 75 nuclear-capable aircraft, and just over 50 SLBMs.

27. Speech by Nicolas Sarkozy, President of the French Republic, Presentation of Le Terrible in Cherbourg, 21 March 2008, www.ipfmlibrary.org/sar08.pdf.

28. Ibid.

29. China's Foreign Ministry declared in April 2004 that China "possesses the smallest nuclear arsenal" among the nuclear-weapon states of the NPT, *Nuclear Disarmament and Reduction of* [sic], Ministry of Foreign Affairs of the People's Republic of China, Fact Sheet China, 27 April 2004, www.fmprc.gov.cn, mirrored at www.ipfmlibrary.org/prc04.pdf.

30. 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.

31. *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.

32. *Highly Enriched Uranium: Striking a Balance. A Historical Report on the United States Highly Enriched Uranium Production, Acquisition, and Utilization Activities from 1945 through September 30, 1996,* Draft, Rev. 1., U.S. Department of Energy, January 2001 (publicly released in 2006), www.ipfmlibrary.org/doe01rev.pdf; updated in *Highly Enriched Uranium Inventory: Amounts of Highly Enriched Uranium in the United States,* U.S. Department Of Energy, 2006, www.ipfmlibrary.org/doe06f.pdf. *Plutonium: The First 50 Years: United States Plutonium Production, Acquisition and Utilization from 1944 through 1994,* U.S. Department of Energy, 1996, www.ipfmlibrary.org/doe96.pdf, updated in *The United States Plutonium Balance, 1944-2009,* U.S. National Nuclear Security Administration, 2012, www.ipfmlibrary.org/doe12.pdf.

33. The 1998 Strategic Defence Review acknowledged that, at that time, the UK military stocks of fissile materials consisted of "7.6 tonnes (metric tons) of plutonium [and] 21.9 tonnes of highly enriched uranium" and also declared 4.4 tons of plutonium excess to military purposes. This surplus material included only 0.3 tons of weapon-grade plutonium, however. All numbers are from "Supporting Essay Five: Deterrence, Arms Control, and Proliferation," §26 in *The Strategic Defence Review,* UK Ministry of Defence, July 1998, www.ipfmlibrary.org/mod98.pdf.

34. D. Albright, F. Berkhout and W. Walker, *Plutonium and Highly Enriched Uranium 1996,* Oxford University Press, 1997; more recently, annual updates by IPFM, in particular, *Global Fissile Material Report 2010, Balancing the Books: Production and Stocks,* IPFM, December 2010, www.ipfmlibrary.org/gfmr10.pdf.

35. IAEA, *Communications Received from Certain Member States Concerning their Policies Regarding the Management of Plutonium,* INFCIRC/549, documents available at www.iaea.org/Publications/Documents/Infcircs.

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

37. 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 http://fissilematerials.org/library/PMDA2010.pdf.

38. For details about the U.S.-Russia-IAEA Trilateral Initiative, see *Global Fissile Material Report 2008,* Chapter 6, IPFM, September 2008. See also discussion on cooperative transparency projects below.

39. IAEA, *The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons,* INFCIRC-153 (corrected), paragraph 14, "Non-Application of Safeguards to Nuclear Material to be Used in Non-Peaceful Activities."

40. *Global Fissile Material Report 2011,* IPFM, January 2012.

41. France previously used HEU to fuel its naval reactors but has moved to LEU fuel.

42. *The United States Plutonium Balance,* 1944-2009, op. cit., Table 5.

43. *Increasing Transparency in the U.S. Nuclear Weapons Stockpile,* U.S. Department of Defense Factsheet, 3 May 2010. In reporting the number of warheads dismantled, the United States distinguished between the total number of warheads disassembled for testing and evaluation, for life extension and dismantled for disposal. The total number of warhead disassemblies (including for dismantlement, life extension, testing and evaluation) are about 1000-1200 per year, of which dismantlements for disposal are now 300-400 per year. Hans Kristensen, personal communication, February 2013.

44. The United States, for instance, has declared all of the 100 nuclear warhead types and their associated delivery systems that it has deployed since 1945 and identified those that remain in service as of 2011, see e.g. United States Department of Defense, *Nuclear Matters Handbook 2011,* www.acq.osd.mil/ncbdp/nm/nm_book_5_11/index.htm. See also Robert S. Norris and Hans Kristensen, "U.S. Nuclear warheads 1945-2009," *Bulletin of the Atomic Scientists,* July/August 2009. The United States has also announced in some cases when the last of a kind of nuclear warhead has been dismantled, e.g. "NNSA Dismantles Last Nuclear Artillery Shell," NNSA news release, 12 December, 2003, http://nnsa.energy.gov/sites/default/files/nnsa/news/documents/PR_NA-03-16_W-76Dismantled-LastNuclearArtilleryShell.pdf; and similarly "NNSA Announces Dismantlement of Last B53 Nuclear Bomb," 25 October, 2011, http://nnsa.energy.gov/mediaroom/pressreleases/b53dismantle102511. The number of weapons of each type that were built was not declared, however.

45. A five-year planning horizon was suggested in *Monitoring Nuclear Weapons and Nuclear-Explosive Materials,* Committee on International Security and Arms Control, National Academy of Sciences, Washington, DC, 2005, Chapter 2 ("Nuclear Weapons") and Table 2-1.

46. *Global Fissile Material Report 2010,* IPFM, 2010.

47. *Update on the Six-Party Talks,* U.S. State Department, Washington, DC, 10 May 10, 2008, http://2001-2009.state.gov/r/pa/prs/ps/2008/may/104558.htm.

48. "First P5 Follow-up Meeting to the NPT Review Conference," Paris, 1 July 2011.

49. *Global Fissile Material Report 2009,* Chapter 5, IPFM, 2009.

50. "UK statement at the UN Disarmament Conference," 4 April 2012.

51. *Global Fissile Material Report 2007,* Chapter 2, IPFM, 2007.

52. The general approach was proposed in Steve Fetter, "Nuclear Archaeology: Verifying Declarations of Fissile-Material Production," *Science & Global Security,* 3, 1993, pp. 237–259. For a summary of U.S. efforts, see Thomas W. Wood, Bruce D. Reid, John L. Smoot, and James L. Fuller, "Establishing Confident Accounting for Russian Weapons Plutonium," *Nonproliferation Review,* Summer 2002, pp. 126–137.

53. *Hanford Site Tours,* Department of Energy, www.hanford.gov/page.cfm/HanfordSiteTours.

54. *France TNP: Turning Commitments into Actions,* www.francetnp2010.fr/spip.php?article110.

55. *Global Fissile Material Report 2010,* Chapter 7, IPFM, 2010.

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. These measures also would be an important step on the path to achieving and sustaining a world free of nuclear weapons. Realizing this objective will require increased transparency about nuclear arsenals and fissile material stockpiles by the nuclear weapon states.

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

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