5. Transparent and Irreversible Dismantlement of Nuclear Weapons

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Key Judgments

- Prohibition of nuclear weapons will require the dismantlement of some 25,000 nuclear weapons that currently exist in nine states. While this dismantlement will pose major operational challenges, facilities and procedures are in place that can accomplish it.
- The nuclear weapons to be eliminated must be: (a) secured and accounted for; (b) committed to dismantlement; (c) placed under bilateral or international monitoring; and (d) verifiably dismantled. The fissile materials from these warheads must then be: (a) placed in secure storage subject to bilateral or international monitoring; (b) committed never to be returned to weapons; and (c) used or disposed of in a way that would make it impossible or very costly to ever return them to weapons use.
- Technologies and procedures are available which, with some refinement and negotiation, can make it possible to build confidence that these warheads have been placed in secure storage and then dismantled as agreed, without compromising sensitive nuclear weapon design information. Technologies and procedures are also available to confirm secure storage and disposition of the fissile materials from these weapons.
- Many nuclear weapons can also be rapidly, verifiably, and permanently disabled pending dismantlement. This would contribute to both arms reduction and theft prevention.
- Building confidence in nuclear arms reductions as they proceed to very low levels will require making these reductions transparent

and difficult to reverse. A comprehensive "transparency and irreversibility" approach would include verifiable dismantlement of delivery systems (and modification of remaining systems to ensure that they could not carry many more than the agreed number of nuclear weapons); verifiable dismantlement of nuclear weapons themselves; disposition of all fissile material beyond the amounts required to support the remaining warheads, along with any agreed remaining purposes (such as naval fuel); and dismantlement or conversion of facilities for producing more delivery vehicles, nuclear weapons, and weapons-useable material.

- If managed appropriately, large-scale nuclear weapon dismantlements and disposition of excess fissile material could reduce the threat of nuclear theft and terrorism. If stringent security measures are not maintained throughout these processes, however, they could *increase* the risk of nuclear terrorism by removing weapons and materials from secure vaults, shipping them from place to place, and processing them.
- Some approaches could make it possible to place thousands of especially dangerous nuclear weapons under internationally monitored lock and key, commit them to eventual verifiable dismantlement, and begin permanently disabling them within months of a decision to do so.

Background

> "*For nuclear disarmament to be real, one has to have procedures for monitoring the dismantling of nuclear munitions and fissionable materials contained in these munitions.*"
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> —Then-Russian First Deputy Minister of Atomic Energy Lev Ryabev, ITAR-TASS, 11 March 1998.

> "*Real disarmament is possible only if the accumulated huge stocks of weapons-grade uranium and plutonium are destroyed.*"
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> —Then-Russian Minister of Atomic Energy Victor Mikhailov, address to the International Atomic Energy Agency (IAEA), quoted by TASS, 22 September 1992.

Implementing deep reductions in nuclear weapons stockpiles, and ultimately the prohibition of nuclear weapons, will require the dismantlement of tens of thousands of nuclear weapons and effective control over the stocks of nuclear material that could be used to rebuild these arsenals. To be successful, this process of nuclear weapons reduction will have to be implemented with enough transparency to give other countries confidence that reductions are taking place as agreed, and in a way that would be difficult, costly, and observable to reverse.

As discussed in the paper on verification, a comprehensive approach will be needed, including declarations of all nuclear weapon and nuclear material stockpiles; measures to confirm and build confidence in the accuracy of those declarations; dismantlement of nuclear weapons, with measures to confirm the dismantlement is taking place; and monitored storage and disposition of excess fissile materials, bringing the stocks of such materials down to the minimum necessary to support whatever stockpiles of nuclear weapons exist at each stage. [See Chapter 4.] There will also have to be comprehensive measures to ensure that all nuclear weapons and materials are secure throughout this process. The greatest challenge will not be in confirming that particular declared warheads are dismantled—the subject of this paper—but in building confidence that there are no hidden stockpiles that have not been declared. Absolute verification of that is impossible—but by exchanging data at a large number of points throughout the nuclear warhead and fissile material life cycles, and comparing the information exchanged with data available from national technical means and other sources, it is potentially possible to build good confidence over time that the declarations are accurate and complete.

Moving forward with such an effort will require fundamental changes in both nuclear weapons policies and nuclear secrecy policies in the nuclear weapon states.[1] It is a remarkable fact that today, sixteen years after the collapse of the Soviet Union, the United States and Russia have never told each other (let alone anyone else) how many nuclear warheads they have, and neither country has verified the dismantlement of a single one of the other country's nuclear warheads.

Numbers of Nuclear Weapons

Today, there are still more than 25,000 assembled nuclear weapons in the world, possessed by nine states. This includes an estimated 15,000 remaining in Russia's stockpile; nearly 10,000 remaining in the U.S. nuclear stockpiles; and over 1,000 warheads in the combined total of other countries' stockpiles.[2] This level of nuclear armament was in-

1. There is a large literature on measures to confirm warhead dismantlement, and other transparency measures for nuclear warheads and materials (of which only a part is classified). For particularly useful recent discussions, see U.S. National Academy of Sciences, Committee on International Security and Arms Control, *Monitoring Nuclear Weapons and Nuclear-Explosive Materials* (Washington, D.C.: National Academy Press, 2005; available at books.nap.edu/catalog/11265.html); Nicholas Zarimpas, ed., *Transparency in Nuclear Warheads and Materials: The Political and Technical Dimensions* (Oxford: Oxford University Press for the Stockholm Peace Research Institute, 2003). The Natural Resources Defense Council and the Federation of American Scientists were early leaders in recognizing the importance of such measures and beginning discussions with Russian experts about what might be done. See, for example, *Third International Workshop on Verified Storage and Destruction of Nuclear Warheads*, Moscow and Kiev, December 1991.

2. See Robert S. Norris and Hans M. Kristensen, "NRDC Nuclear Notebook: Russian Nuclear Forces, 2007," *Bulletin of the Atomic Scientists* (March/April 2007);

Table 1: World Nuclear Weapon Stockpiles

Country	*# Weapons*	*% of World*
Russia	15,000	58%
United States	10,000	39%
France	350	1%
China	200	0.75%
United Kingdom	200	0.75%
Israel	60–80	0.5%
India	50–60	0.3%
Pakistan	40–50	0.2%
North Korea	10	0.04%
TOTAL	26,000	100.00%

Sources: Robert S. Norris and Hans M. Kristensen, "NRDC Nuclear Notebook: Global Nuclear Stockpiles 1945–2006," *Bulletin of the Atomic Scientists*, July/August 2006, updated with the following editions of the "NRDC Nuclear Notebook": for Russia: March/April 2007; for the United States: January/February 2007.

sane in Cold War times; more than a decade later, nuclear arsenals of this size clearly pose far more risk than benefit.

The five states with the largest number of nuclear weapons are the five nuclear weapon state parties to the nuclear Nonproliferation Treaty (NPT): Russia, the United States, China, France, and the United Kingdom. The four other states with nuclear weapons are the only states outside the NPT (North Korea being the only country to have joined the treaty and then withdrawn). See Table 1. In addition to these nine countries that possess nuclear weapons of their own, U.S. nuclear weapons are reportedly located in six other countries—one other nuclear weapons state (the United Kingdom) and five non-nuclear weapons states (Germany, the Netherlands, Belgium, Italy, and Turkey).[3] The larger the number of individual locations where such weapons exist, the higher the risks of accident or theft.

Robert S. Norris and Hans M. Kristensen, "NRDC Nuclear Notebook: U.S. Nuclear Forces, 2007," *Bulletin of the Atomic Scientists* (September/October 2007); Robert S. Norris and Hans M. Kristensen, "NRDC Nuclear Notebook: Global Nuclear Stockpiles, 1945–2006," *Bulletin of the Atomic Scientists* (July/August 2006).

3. As a result of the 1991 Presidential Nuclear Initiatives, U.S. nuclear weapons have been removed from South Korea and from surface ships, which previously reg-

Dismantlement Capacity

The specific steps involved in dismantlement of a nuclear weapon vary somewhat depending on the type of weapon. In general, dismantlement involves removing the weapon itself, or the "physics package" from the outer shell and other components, separating the high explosives from the fissile materials in the weapon, and destroying, storing, or re-using the various weapon components.

In both the United States and Russia, and presumably in other nuclear weapon states as well, nuclear weapons are typically dismantled in the same facilities where they were assembled, as those facilities have the experience and the tooling needed to handle that particular warhead type. The only operational nuclear weapon assembly/disassembly facility in the United States is at Pantex, in Amarillo, Texas. (The Device Assembly Facility [DAF] at the Nevada Test Site was designed to assemble small numbers of nuclear weapons for nuclear tests, but has never been used for that purpose.) Russia has two remaining nuclear weapon assembly/disassembly facilities, at the closed nuclear cities of Lesnoy (formerly Sverdlovsk-45) and Trekhgornyy (formerly Zlatoust-36).

The United States maintained an average dismantlement rate of some 1,300 weapons per year during 1990–1998; in some of those years, the United States dismantled as many as 1,800 weapons. For recent years, dismantlement rates have declined dramatically, though specific numbers are classified. Reportedly, the dismantlement rate in 2003 and the years immediately following was in the range of 130 weapons per year. The Department of Energy (DOE) informed Congress that the rate in 2007 would be 50 percent higher, but that would

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ularly carried them to countries around the world. The deployments in Europe, and on submarines, are believed to be the only remaining U.S. nuclear weapons deployments beyond U.S. shores. For a detailed discussion of the remaining U.S. nuclear weapons in Europe, see Hans M. Kristensen, *U.S. Nuclear Weapons in Europe: A Review of Post-Cold War Policy, Force Levels, and War Planning* (Washington, D.C.: Natural Resources Defense Council, 2005).

still bring the total to only about 200 warheads per year. Independent experts have estimated that the Bush administration's announced plans to reduce the U.S. nuclear weapons stockpile would, if implemented as planned, eliminate roughly 5,000 of the nuclear weapons in the U.S. stockpile. DOE reports that it plans to complete those dismantlements by 2023, which would suggest a planned dismantlement rate in the range of 300 weapons per year.[4]

This slow pace is primarily the result of warhead dismantlement not being treated as a high priority. Instead, a substantial part of the capacity at Pantex is being devoted to refurbishing existing warheads to extend their lives decades into the future. If dismantlement were made a top priority, it is likely that Pantex could again dismantle more than 1,000 nuclear weapons per year.

The situation appears to be similar in Russia, though Russia is believed to have a larger backlog of weapons that are not in use and are slated for eventual dismantlement. In the 1990s, by some estimates, Russia was dismantling as many as 2,000 nuclear weapons per year. In recent years, Russia has closed two of its four warhead assembly/disassembly facilities (though the two closed facilities, at Sarov and Zarechnyy, had much smaller capacities than the two remaining facilities). One independent estimate suggests that Russia is now dismantling some 400–500 warheads a year, but remanufacturing perhaps 200 of them, for a net dismantlement rate in the range of 200–300 per year.[5] Like the United States, it is likely that if Russia made dismantlement a priority, it would have the capability to dismantle more than 1,000 nuclear weapons per year.

Less is known about nuclear weapons assembly and disassembly

4. For discussions of these points, see Chapter 5 in International Panel on Fissile Materials, *Global Fissile Materials Report 2007* (Princeton, NJ: IPFM, October 2007) and Robert S. Norris and Hans Kristensen, "NRDC Nuclear Notebook: The U.S. Nuclear Stockpile, Today and Tomorrow," *Bulletin of the Atomic Scientists* (September/October 2007).

5. Anatoli Diakov, cited in *Global Fissile Materials Report 2007*, p. 62.

capacities in other countries. Other countries, however, have nuclear stockpiles measured in hundreds of warheads or less; it is likely that these stockpiles could be dismantled relatively quickly if a decision were taken to do so. In short, it appears that it would be technically possible to dismantle all the world's nuclear weapons over a period of 10–20 years.

Past Discussions of Verified Dismantlement and Related Measures

Nuclear weapons themselves are smaller and easier to hide than the missiles and bombers that deliver them. To date, nuclear arms control and reduction agreements have focused on reducing delivery vehicles, not on dismantlement of the nuclear weapons themselves. It has long been understood, however, that as reductions proceed to lower levels, restraints on nuclear weapons themselves, and on the fissile materials needed to make them, will become increasingly important.[6] Official studies of approaches to verifying warhead dismantlement have been underway in one form or another for over forty years.

During the 1990s, the United States and Russia pursued a series of discussions focused on "Safeguards, Transparency, and Irreversibility" (STI) of nuclear arms reductions. By 1995, the U.S. and Russian presidents had agreed to exchange data on how many nuclear weapons and how much fissile material each side had, and a number of transparency and irreversibility commitments were included in a 1995 joint summit statement. The United States made a proposal that called for a detailed data exchange, and for reciprocal visits to fissile material sites to help build confidence in the accuracy of the data. (At that time, verified warhead dismantlement was not included in the proposal.) While Soviet and Russian negotiators had, in the past, agreed to a series of intrusive on-site inspection measures as part of

6. See discussions in U.S. National Academy of Sciences, *Monitoring Weapons and Nuclear-Explosive Materials*; and Zarimpas, ed., *Transparency in Nuclear Warheads and Materials*.

negotiating arms reduction agreements that they believed served their country's interest, in this case the transparency measures were proposed independently of any associated arms reductions—and would have affected not just missiles, bombers, and submarines, but nuclear weapons and materials themselves. Secrecy and suspicion were still pervasive among the nuclear security and counterintelligence establishments in both Russia and the United States. Russia appears to have concluded that the U.S. proposals for data exchange were so broad that they constituted, in effect, an intelligence fishing expedition. Ultimately, these proposals went nowhere, and no data exchanges occurred.[7]

At the Helsinki summit in 1997, however, President Bill Clinton and Russian President Boris Yeltsin agreed that a START III agreement should include "measures relating to the transparency of strategic nuclear warhead inventories and the destruction of strategic nuclear warheads . . . to promote the irreversibility of deep reductions including prevention of a rapid increase in the number of warheads." The two presidents also instructed their experts to "explore, as separate issues" (that is, presumably not as part of a START III agreement itself) "possible measures relating to nuclear long-range sea-launched cruise missiles and tactical nuclear systems, to include appropriate confidence-building and transparency measures," and agreed to "consider the issues related to transparency in nuclear materials." In the discussions that followed, the United States proposed a protocol on nuclear warhead transparency and monitoring in early 2000, but Russian negotiators did not appear interested in pursuing this idea. Ultimately, formal START III negotiations never began. The Bush administration has not chosen to pursue any discussions focused on monitored reductions in nuclear weapon stockpiles.

7. The best published account of these discussions is from James Goodby, the lead U.S. negotiator. See James Goodby, "Transparency and Irreversibility in Nuclear Warhead Dismantlement," in *The Nuclear Turning Point: A Blueprint for Deep Cuts and De-Alerting of Nuclear Weapons*, Harold A. Feiveson, ed. (Washington, D.C.: Brookings, 1999).

Since the 1990s, however, experts from U.S. and Russian nuclear laboratories have cooperated extensively to develop options for confirming warhead dismantlement without revealing sensitive nuclear weapons design information, along with other transparency approaches related to nuclear warheads and fissile materials.[8] (As these efforts included a number of approaches to detection of nuclear material and high explosives, they have been refocused on counterterrorism missions in the aftermath of the 9/11 attacks, but the cooperation is continuing.) These efforts provide a substantial technical base on which to draw for future agreements on verified warhead dismantlement.

In addition, cooperation on threat reduction has formed habits of cooperation and opened many categories of information. Cooperation to destroy, and confirm the destruction of, ballistic missiles, bombers, and submarines is now routine. In the course of cooperation to improve security for nuclear stockpiles, U.S. experts have visited the vast majority of the buildings in Russia's nuclear weapons complex and numerous nuclear warhead storage sites, with only actual warhead assembly/disassembly facilities and a few buildings at other sites remaining off-limits; Russian experts have visited most of the facilities of the U.S. nuclear weapons complex, including Pantex, the nuclear weapons assembly/disassembly plant.

Moreover, while Russia and the United States have not negotiated any broad transparency regime for nuclear warheads and fissile materials, or any measures specifically related to verifying warhead dismantlement, a few "islands of transparency" have been implemented for particular purposes, and others are still being pursued. The most successful example is the transparency for the U.S.-Russian Highly Enriched Uranium (HEU) Purchase Agreement, under which U.S. monitors visit facilities and check activities related to chopping HEU

8. For a useful overview, see Oleg Bukharin, "Russian and U.S. Technology Development in Support of Nuclear Warhead and Material Transparency Initiatives," in Zarimpas, ed., *Transparency in Nuclear Warheads and Materials*.

warhead components into metal shavings, oxidizing them, purifying them, converting them to uranium hexafluoride, and blending them to low-enriched uranium. Russian monitors check at U.S. facilities to make sure the material delivered is used only for peaceful purposes. Unmanned equipment continuously monitors the actual blending of the HEU to low-enriched uranium.[9] Despite years of effort, a transparency accord for the Mayak Fissile Material Storage Facility had not been reached by early 2008; negotiations continue over monitoring plutonium produced in the plutonium production reactors, and monitoring disposition of excess plutonium.

Issues

What needs to be done pending dismantlement?

Verified dismantlement of nuclear weapons would be only one element in a broader political and technical regime for secure, transparent, and irreversible nuclear arms reductions. In particular, if *X* thousand weapons are to be dismantled, it would be extremely important to know how many there were to start with, and how many will remain after a particular agreed stage of dismantlement is completed.

Hence, a key first step is a comprehensive declaration of how many nuclear weapons each side has. An accompanying declaration concerning the quantities of separated plutonium and HEU would also be important. There is a wide range of possibilities for the kinds of information to be included, how the information would be exchanged, and the measures to be used to build confidence in the accuracy of the declarations.[10]

9. See Matthew Bunn, with James Platte, "Highly Enriched Uranium Transparency," in *Nuclear Threat Initiative Research Library: Securing the Bomb* (Cambridge, Mass., and Washington, D.C.: Project on Managing the Atom, Harvard University and Nuclear Threat Initiative, 2006; available at www.nti.org/e_research/cnwm/monitoring/uranium.asp as of March 2, 2007).

10. For example, if it were considered too sensitive to exchange complete data at present, the two sides could exchange message digests in the form of a secure hash;

In addition, the nuclear weapons to be eliminated must be placed in highly secure storage, and committed to dismantlement—at least as a political commitment initially, or perhaps in a legal agreement. They should then be placed under either bilateral or international monitoring, to confirm that they remain in storage and have not been removed, and remain highly secure.

Since there are nine states with nuclear weapons, and many more with a strong interest in nuclear disarmament, nuclear disarmament will inevitably be a multilateral enterprise. At some stage, monitoring by some international group is likely to be required, to convince all states, not just the United States and Russia, that weapons are being eliminated as agreed. Monitoring by the IAEA, in particular, has a credibility with the vast majority of the world's states (which are already subject to IAEA monitoring) that bilateral monitoring by the United States and Russia will never achieve. But in the near term, there is probably a great deal the United States and Russia would be willing to open to verification bilaterally that they would not be willing to allow international inspectors—who might come from states suspected of pursuing nuclear weapons themselves—to monitor. The best balance between bilateral and international inspection, and the process for transitioning from the one to the other, requires further study.

If desired, nuclear warheads can also be disabled pending their eventual dismantlement, so that they could no longer be detonated; this could reduce the risk these weapons would pose if they were stolen, and, if done in a way that was difficult to reverse, could make it possible to eliminate the capability of these weapons more rapidly than they can actually be dismantled. One approach that could be applied to many warhead types, which could also contribute to veri-

these digests themselves would contain no useful information, but would allow information provided later from the data the digests came from to be confirmed as authentic. See discussion in U.S. National Academy of Sciences, *Monitoring Nuclear Weapons and Nuclear-Explosive Materials*, pp. 92–94.

fication of disablement and dismantlement, is referred to as "pit-stuffing." Modern boosted thermonuclear weapons typically have a hollow-shell primary, or "pit," surrounded with high explosives. A tube leads from the outside of the pit to the inside, allowing tritium to be injected into the pit for boosting. If the hollow pit is filled with other material—such as wire inserted through the pit tube—the explosives can no longer crush the pit to a critical configuration and the weapon cannot go off. Steps can be taken to make it effectively impossible to pull the wire back out without disassembling the weapon and cutting open the pit (such as equipping the wire with small toggle bolts similar to those used to mount shelves on hollow walls, for example). Monitors could observe as the inspected party inserted such wires before the weapons were disassembled (with appropriate shrouds used to avoid revealing sensitive information); a gamma-ray image of a small section of the warhead could confirm that it contained a hollow plutonium shell with a tangle of metal inside it.[11] Pit-stuffing, however, could not be applied to all nuclear weapon types. Moreover, it has received only a modest level of study, and further detailed examinations of implementation issues would be needed before this approach could be adopted on a large scale.

As discussed further below, these steps could in principle be taken relatively quickly—in many cases within months or a year after a decision to do so. Once the warheads are secure, under monitoring, and committed to dismantlement, the dismantlement itself can proceed at the careful pace required.

What is the best approach to confirming dismantlement?

A variety of approaches to building confidence that dismantlement is taking place as agreed have been proposed; these offer varying levels of confidence and varying obstacles to implementation.

11. See Matthew Bunn, "'Pit-Stuffing': How to Rapidly Disable Thousands of Warheads and Easily Verify Their Dismantlement," *F.A.S. Public Interest Report*, March/April 1998, with commentary by Richard L. Garwin.

If there were high confidence that there were no secret stockpiles of unassembled nuclear weapons components, the simplest approach would be simply to monitor disassembled nuclear weapon components building up in storage. Each additional nuclear weapon primary, or "pit," being added to storage would be assumed to mean one additional weapon dismantled. This approach is simple, low-cost, and avoids the sensitivities of monitoring at dismantlement sites, but is relatively low confidence, since the pits building up in storage might possibly be coming from some secret stockpile or from new manufacturing, if those possibilities were not effectively monitored. If the focus is on very deep reductions, and potentially complete nuclear disarmament, this approach alone is probably insufficient, though it can contribute in concert with other approaches.

Another approach, known as "chain of custody," would track nuclear weapons up to the door of the building or area where the weapon was to be dismantled, and then track their components when they left the building. Unless other monitoring measures were included, however, it would be possible to bring warheads in and bring them back out again without dismantling them, and bring components in and bring them back out as though they were from dismantled weapons.

Hence, many analyses have focused on "perimeter-portal" monitoring. In this approach, inspectors would count the number of warheads entering the perimeter of a dismantlement facility, through one or more agreed portals; and the number of fissile material components leaving the facility.[12] There would be occasional inspections of the interior of the facility (during periods when no nuclear weapons were being dismantled) to confirm that there was no buildup of nuclear weapons or materials within the facility.

12. If the same facility were also remanufacturing weapons for maintenance purposes, the monitors could count the number of weapons going in and the number coming out, to determine the *net* number going in. Alternatively, remanufacturing could be segregated at a different facility or area of the facility; some monitoring would still be needed to ensure that what was taking place was not the production of significant numbers of new warheads.

A key issue in such approaches is how to confirm that an object entering the dismantlement facility that is declared to be a warhead is in fact a warhead. Two main approaches have been examined, one based on "attributes"—characteristics that all nuclear warheads and few other objects would generally have—and the other based on "templates"—detailed signatures specific to particular warhead types.[13] In an attribute approach, for example, the parties might agree that an object that was declared to be a nuclear weapon, was of an appropriate size to be a nuclear weapon, was confirmed by detectors to contain at least *x* kilograms of weapons-grade plutonium in metal form, and which was also confirmed to contain high explosives in close proximity to the plutonium, would be considered a nuclear weapon.[14] Key disadvantages include the need to have very broad standards in order to encompass all the varying characteristics of different types of nuclear weapons, and the possibility the system could be spoofed with dummy objects that contained explosives and weapons-grade plutonium but were not weapons. (Whether there would be any incentive for a party to go to the considerable expense of manufacturing hundreds or thousands of objects that contained weapons-grade plutonium metal and high explosives but were not weapons is an open question.)

In the "template" approach, measurements—typically radiation measurements, but others could be used as well—would be taken on particular warhead types, and the signatures from these measurements would be compared to the signatures from objects declared to be weapons of that type entering a dismantlement facility. In U.S. tests, such systems have shown an excellent ability to distinguish real weapons from other objects. A key issue for the "template" approach is how to confirm that the objects measured to get the templates are actually nuclear weapons: in the case of weapon types still deployed

13. See, for example, U.S. National Academy of Sciences, *Monitoring Nuclear Weapons and Nuclear-Explosive Materials*, pp. 97–106.

14. Except in nuclear weapons, high explosives are generally kept separately from radioactive materials for safety reasons.

on strategic ballistic missiles, this may not be a great difficulty, as particular missiles could be selected at random and measurements taken on one of their warheads. But in the case of air-delivered bombs and other weapons that are all in storage, the task of confirming that the templates are themselves authentic is a non-trivial one.

The “pit-stuffing” approach just described could also be used to confirm nuclear weapon dismantlement. As already noted, a gamma-ray image of a small section of the weapon (from outside a container) could confirm that it contained a hollow plutonium shell with a tangle of metal inside it; after dismantlement, a similar gamma-ray image could confirm that a container which was declared to be the pit from that weapon could confirm that it also contained a hollow plutonium shell with a tangle of metal.[15] As noted earlier, the approach could not be used for all warhead types, and would require additional study before implementation.

All of these approaches have advantages and disadvantages. In the end, it is likely that some combination of these approaches will be required.

All of these approaches pose the problem that the measurements of radiation from nuclear warheads and components that they require are likely to contain sensitive information. To deal with that problem, a variety of approaches to “information barriers” have been developed—systems which would take the measurements in a way that could be authenticated, but would tell the monitors only “yes” or “no”—the object had the expected attributes or template, or it did not. To ensure that these systems could not be programmed to report, for example, that an object was a nuclear weapon when it was not, the systems can be built with simple hardware and software, where every line of the code can be inspected; arrangements can also be made in which the systems are built by the inspecting side, which would build extra copies of the systems so that the inspected side could choose

15. Bunn, “Pit-Stuffing.”

which one would be used and take another apart to confirm that it was not designed to collect information beyond that agreed to. The "template" approach poses particularly difficult challenges for the protection and control of sensitive information, since the radiation templates themselves would be highly sensitive and would have to be stored and moved from place to place.[16]

In short, technologies and procedures are available which can make it possible to confirm the dismantlement of declared nuclear weapons with reasonable confidence, without revealing sensitive nuclear weapon design information.

What should be done with fissile materials from dismantled weapons?

If dismantlement is to be permanent, the huge stockpiles of plutonium and HEU that now exist must also be addressed. Once weapons are dismantled, the first steps would be to place the resulting fissile materials in highly secure storage facilities; commit them never again to be used in nuclear weapons; and open them to bilateral or international monitoring.

Over time, stockpiles of fissile materials should then be reduced to the minimum required to support the remaining nuclear weapon stockpiles at each stage (and to support whatever other purposes for these materials are still permitted, such as the use of HEU for naval fuel).[17]

A comprehensive program to make it difficult, costly, and observable to reverse nuclear arms reductions would include verifiable dismantlement of delivery systems (and modification of remaining systems to ensure that they could not carry many more than the agreed

16. See U.S. National Academy of Sciences, *Monitoring Nuclear Weapons and Nuclear-Explosive Materials*, pp. 107–8.

17. U.S. National Academy of Sciences, Committee on International Security and Arms Control, *Management and Disposition of Excess Weapons Plutonium* (Washington, D.C.: National Academy Press, 1994).

number of nuclear weapons); verified dismantlement of nuclear weapons themselves (as just discussed); disposition of all fissile material beyond the amounts required to support the remaining warheads, along with any agreed remaining purposes; and dismantlement or conversion of facilities for producing more delivery vehicles, nuclear weapons, and weapons-useable material. Disposition of excess HEU and plutonium would be one very important element of this program, but only one.

Technically, reducing HEU stockpiles is straightforward, as HEU can be blended with other uranium to produce low-enriched uranium (LEU) that cannot be used in a nuclear bomb but is the standard fuel for commercial nuclear power plants. This approach is already being implemented on a large scale: the U.S.-Russian HEU Purchase Agreement has already destroyed enough HEU for more than 10,000 nuclear weapons. Remarkably, roughly one in ten light bulbs in the United States is fueled with material from dismantled Russian nuclear weapons. Additional blending of HEU to LEU, if managed appropriately so as not to damage uranium and enrichment markets, can help address current shortages of uranium and enrichment services, filling the gap until additional uranium mines and enrichment capabilities are brought on-line to support a growing nuclear energy enterprise.

Disposition of excess plutonium is more difficult. As nearly all mixes of plutonium isotopes can be used in a nuclear bomb, simple blending with other plutonium does not eliminate the security hazard posed by plutonium as it does in uranium's case. Plutonium can be mixed with uranium to produce a mixed oxide (MOX) that can be used as reactor fuel—but doing so is more expensive than using LEU fuel (except when uranium prices are unusually high), even if the plutonium itself is considered "free." Alternatively, plutonium can be immobilized and disposed of as a waste, possibly mixed with highly radioactive fission products to provide a radiation barrier to any effort to recover the plutonium for use in nuclear weapons. Either of these means could make the plutonium from excess nuclear weapons as difficult to use in weapons as the much larger amount of plutonium in the spent fuel from commercial power reactors around the world—the “spent fuel standard.”

It is essential to ensure that the highest practicable standards of security and accounting are maintained throughout these processes. Otherwise, removing these materials from secure vaults, processing them in bulk, and shipping them from place to place could *increase,* rather than decrease, the risk of nuclear theft. Measures that are already being implemented for the HEU Purchase Agreement and for civilian use of HEU and plutonium can verify the disposition of these materials.[18]

What distinctions should be made between strategic and tactical warheads?

Arms control negotiations to date have focused primarily on strategic nuclear weapons. Only the voluntary and unverified 1991–1992 Presidential Nuclear Initiatives, and other unilateral decisions, have led to large-scale reductions in tactical nuclear weapons.

The United States has sought at least transparency measures for tactical nuclear warhead stockpiles. Russia, which has a large tactical stockpile it regards as an important backup for its comparatively weak conventional forces, has been reluctant to pursue formal controls on tactical nuclear weapons.

Initially, it is very likely that reductions in strategic weapons and in tactical nuclear weapons will be pursued separately. As reductions proceed to low levels, however, it would be desirable to focus more simply on the total number of nuclear weapons. Attempting to distin-

18. For a seminal discussion of these issues, see Committee on International Security and Arms Control, *Management and Disposition of Excess Weapons Plutonium.* For recent updates, see Matthew Bunn and Anatoli Diakov, “Disposition of Excess Highly Enriched Uranium,” and “Disposition of Excess Plutonium,” in International Panel on Fissile Materials, *Global Fissile Materials Report 2007* (Princeton, N.J.: IPFM, October 2007).

guish strategic nuclear weapons from tactical nuclear weapons in approaches to monitoring warhead dismantlement introduces substantial complications—particularly as some weapon types are used for both tactical and strategic purposes. Thus, the ultimate objective should be a transparency and reductions regime that applies to all nuclear weapons and the stocks of fissile material needed to make them.[19]

What is the best balance between transparency and secrecy?

Activities related to nuclear weapons remain shrouded in secrecy. While there has been some increased transparency in some weapons states (particularly the United Kingdom and the United States), the secrecy remains pervasive. So far, secrecy concerns have blocked transparency measures of the kind described in this paper. Although the United States and Russia came close to completing negotiation of a legal framework for exchanging classified nuclear information in the 1990s, many people in the nuclear and security establishments of the United States, Russia, and other weapons states remain extraordinarily reluctant to change traditional secrecy policies.[20]

Ultimately, however, a program of deep, transparent, and irreversible nuclear arms reductions, pointing in the direction of nuclear prohibition, will require major changes in secrecy policies. Increased

19. See, for example, U.S. National Academy of Sciences, *Monitoring Nuclear Weapons and Nuclear-Explosive Materials*.

20. An anecdote illustrates the degree of the problem, even in the United States, which has allowed more transparency than most nuclear weapon states. In the 1990s, after President Clinton announced that excess U.S. plutonium and HEU would be submitted to International Atomic Energy Agency (IAEA) monitoring, the National Security Council staff directed the State Department to chair an interagency discussion of what monitoring measures IAEA inspectors could be allowed to conduct on containers that held components from dismantled weapons without revealing sensitive information. At the meeting, the representatives from the Defense Department and the Defense Programs part of the Department of Energy said that they objected to even holding such an interagency meeting, and that they would not even describe the reasons for their objections. For an argument of the near-completion of the agreement for exchange of classified information, see Goodby, “Transparency and Irreversibility in Nuclear Arms Reductions.”

transparency will be required to build international confidence in the ongoing reductions process, and to help each party be confident in the size and management of the others' remaining nuclear stockpiles.

In general, the rule should be that all information related to nuclear weapon design and information that could substantially contribute to planning a nuclear theft should remain secret. All other information could be exchanged, either publicly or on a confidential basis, to the extent to which it contributes to the joint objective of transparent reductions. For each piece of information to be exchanged or opened to monitors, there should be a consideration of the benefits and the risks of providing that information, and it should be provided wherever the benefits outweigh the risks.

What warhead and fissile material reduction initiatives could have significant security benefits quickly?

It is not possible to dismantle thousands of nuclear weapons quickly. There are, however, a number of initiatives that could have significant security benefits and could be implemented quickly:

- The United States and Russia could launch another round of reciprocal reduction initiatives, while adding limited monitoring arrangements. Thousands of nuclear weapons could be placed in secure storage, committed to eventual verified dismantlement, and opened to monitoring by the other side—in effect placing them under jointly monitored lock and key—within months of a decision to do so. Ideally, such initiatives should include particularly warheads that pose particular security risks—such as readily portable tactical weapons not equipped with modern, difficult-to-bypass electronic locks.
- Commitments can be made quickly. A U.S.-Russian commitment to pursue deep reductions in their nuclear stockpiles, to implement verified dismantlement of weapons, to reduce their plutonium and HEU stockpiles to the minimum required to support reduced nu-

clear weapon stockpiles, and to open all excess plutonium and HEU to international monitoring could radically transform international perceptions of their commitment to fulfilling their nuclear disarmament obligations. This could be particularly important in the lead-up to the 2010 NPT review conference.

- The United States and Russia already have large stockpiles of plutonium and HEU which have already been declared to be in excess of their military needs. In their Trilateral Initiative with the IAEA, they have already developed legal and technological approaches to placing these materials irrevocably under international monitoring, without revealing sensitive information. A U.S. and Russian announcement that they would open thousands of bombs' worth of material to international monitoring could, in itself, have significant benefits for building support for the nonproliferation regime.
- Declarations of total numbers of nuclear weapons and total stockpiles of fissile materials can be exchanged essentially as soon as decisions can be taken to do so. The sooner such declarations are exchanged, the sooner the governments involved can begin building confidence in their accuracy and completeness.

Recommendations

- The United States and Russia, eventually joined by all other states, should work to build a comprehensive transparency regime for nuclear warheads and fissile materials, including measures to confirm the dismantlement of nuclear weapons. This regime should be designed to provide confidence in the size and security of nuclear stockpiles, and confidence in the process of reducing them.
- The United States and Russia should move quickly to commit themselves to deep reductions in their stockpiles of nuclear weapons and materials. Ideally, this commitment should be made prior to the opening of the 2010 NPT review conference. All states should eventually join in these reductions.

- The United States and Russia should move quickly to put thousands of unneeded nuclear weapons in secure, jointly monitored storage, and commit them to be dismantled verifiably as soon as appropriate arrangements can be agreed. They should also take steps to disable these weapons pending dismantlement. Such measures should be considered as part of a post-START reductions and verification regime.
- The United States and Russia should move rapidly to place all of their excess plutonium and HEU under IAEA monitoring—ideally prior to the opening of the 2010 NPT review conference.
- The United States and Russia should work with other nuclear weapons states and non-nuclear weapons states to agree on approaches to confirming warhead dismantlement that all concerned can have confidence in.
- All states participating in dismantlement of nuclear weapons and disposition of excess nuclear material should ensure that the highest practicable standards of security and accounting are maintained throughout these processes.