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Status Report on Fissile Materials:

Paths to Deep Reductions and Nuclear Disarmament

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INTERNATIONAL CONTROLS ON PLUTONIUM AND HIGHLY enriched uranium (HEU), the chief fissile materials used in nuclear weapons, are necessary to help stop the proliferation of nuclear weapons to other countries and terrorist groups and to make deep nuclear arms reductions irreversible. It is vital that existing international controls be strengthened. Reducing the threat posed by fissile materials also will require extending controls over stocks and production programs that currently are beyond their reach.

Because the Nuclear Non-Proliferation Treaty's (NPT's) five nuclear weapon states, especially the United States and Russia,

possess the vast majority of these stocks, they bear the greatest responsibility for taking steps to improve this situation.[1] Moreover, such steps are necessary to create a regime capable of verifying deep reductions in nuclear arsenals. As deeper reductions take effect, controls on the fissile materials removed from these weapons, and on other existing military and civil stocks, will be required to assure that nuclear weapons are not being assembled or stored in secret. The three smaller nuclear weapon states—China, France, and the United Kingdom—also need to apply similar controls so that they will be prepared to join the arms reduction process once arsenals in Russia and the United States are reduced to very low levels.

The NPT's non-weapon state members must broaden existing international controls on their nuclear programs to reduce the proliferation threats posed by fissile materials. These efforts also are required to complement the disarmament process in the weapon states. As Hans Blix, the former director general of the International Atomic Energy Agency (IAEA), wrote, "The process of [reducing] nuclear weapons will be accompanied by the demand for increased insurance that such weapons are not being acquired by others."[2] This will require the non-weapon states to make their civil nuclear programs even more transparent than they currently are, and to accept increasingly strengthened international safeguards that aim to detect undeclared nuclear activities.

The May 1998 nuclear tests by India and Pakistan have made the need for broadened and strengthened fissile material controls more urgent than ever. Following the South Asian tests, some of the NPT's non-nuclear weapon states may reconsider their views on nonproliferation, concluding that nuclear weapons accord status, prestige, and security to their possessors. Arguments supporting this conclusion would be bolstered by India and Pakistan's long-standing claim that the NPT regime perpetuates a monopoly on the possession of nuclear weapons by the five weapon states. To reaffirm the importance of the NPT regime to preserving international security, the

nuclear weapon states need to take further steps to delegitimize nuclear weapons by making deep, verifiable, and irreversible nuclear arms reductions. Fissile material controls are vital to the success of these efforts.

Ultimately, the de facto nuclear weapon states—India, Israel, and Pakistan—also will be expected to place international controls on their fissile materials. This process could most profitably begin with the negotiation and conclusion of a multilateral fissile material cutoff treaty (FMCT), which would end the production of fissile materials for nuclear weapons purposes. It is widely recognized that an FMCT would ease tensions between India and Pakistan in South Asia, and also would serve as a valuable confidence-building measure in the Middle East.

International Declarations of Military and Civil Stockpiles

Information about fissile material stockpiles and production capabilities in all states is vital to efforts to reduce the risks posed by these materials and to achieve significant nuclear arms reductions. Governments have done too little to assemble and provide such information to each other and to the public. Many governments keep secret their plutonium and HEU stockpiles—military and civilian—and their production capabilities. The nuclear weapon states, which have the largest proportion of these materials, appear to have the least accurate accounting of their inventories.

An important goal of efforts to control fissile materials world-wide is to create an international fissile material registry.[3] An official, comprehensive, world-wide inventory of fissile materials does not exist. On an individual basis, states lack accurate information about the fissile material holdings of other states, particularly of their military stocks. Only crude estimates of military fissile material stocks are possible; in some cases, governments may not have accurate knowledge about their own military stocks.

An international fissile materials registry would include, on a

state-by-state basis, detailed information about plutonium and HEU stockpiles and production capabilities. As William Walker recommends in Chapter II, such a registry would include: the best information available about total HEU and plutonium inventories, including weapon- and non-weapon-grade materials; the quantity of material dedicated to nuclear weapons or naval propulsion purposes; the quantity of material that is determined to be excess to military needs; and information about the steps to be taken to place excess material under international controls.

Accurate information about the size of civil fissile material stocks on a state-by-state basis is much more developed than information about military stocks. Recently, a group of key states—Belgium, China, France, Germany, Japan, Russia, Switzerland, the United Kingdom, and the United States—agreed to publish information about their separated civil plutonium holdings.[4] Each of these states—including Russia—has declared its civil stocks to the IAEA through 1996 (some through 1997), and promised to update these declarations annually.[5]

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However, state-by-state information about civil HEU stocks is insufficiently transparent, particularly among Euratom members. Although several Euratom members have agreed to seek a format to declare their civil HEU holdings, only Britain has declared the size of its civil stock.[6]

Among the de facto nuclear weapon states, India possesses hundreds of kilograms of separated civil plutonium. However, India has refused to declare its civil plutonium holdings. Pakistan and Israel are not believed to have substantial unsafeguarded civil fissile material stocks.

The nuclear weapon states have yet to achieve the level of accuracy about their military stocks that the non-weapon states have reached in reporting information about civil holdings. Making their nuclear programs more transparent will require

the nuclear weapon states to collect information about the size, form, location, and production history of their stocks. Assembling this information about military stockpiles is difficult, given that the nuclear weapon states neglected this type of record-keeping, especially in the early years of their programs. Cold War habits of secrecy, which hid such information from the public, are also hard to break.

Efforts to assemble and release information about military stocks require significant political leadership, time, and resources. In February 1996, following a two-year effort, the U.S. Department of Energy (DOE) released a comprehensive report detailing information about the U.S. plutonium stockpile and production history. The release of a similar report on U.S. HEU production, acquisition, and use has been delayed significantly because of the complexity of the data being reviewed and for classification reasons.[7] Report preparation has been further complicated by the closure of facilities and the retirement or death of key personnel who know how to interpret the assembled data.[8]

Britain has announced that it will release a historical report about its fissile material production and acquisition effort since the 1940s. A preliminary report is planned for release in spring 2000. Russia, France, and China have been silent about the size and production history of their military stocks.

Bilateral or multilateral agreements to share information are alternatives to an international registry, but such arrangements are less transparent. Attempts to negotiate arrangements to share information about military stocks have not succeeded. In May 1995, Presidents Bill Clinton and Boris Yeltsin pledged "to establish as soon as possible concrete arrangements for enhancing transparency and irreversibility" in nuclear arms reductions.[9] In particular, Clinton and Yeltsin affirmed "the desire . . . to exchange detailed information on aggregate stockpiles of nuclear warheads [and] stocks of fissile materials . . . on a regular basis."[10] But negotiations soon faltered when the two sides failed to agree to exchange classified information. Although

Clinton and Yeltsin agreed at their March 1997 Helsinki summit that the next Strategic Arms Reduction Treaty (START III) negotiations would include transparency measures related to strategic warhead inventories, it is not known whether such measures will include broad information exchanges about fissile material stocks.

Ending the Production of Plutonium and HEU for Weapons

The primary objective of an FMCT is to verifiably stop the production of HEU and separated plutonium for nuclear explosive purposes. The non-weapon states already have made legally binding commitments to forgo the production of plutonium and HEU for nuclear weapons as part of their NPT obligations, but the weapon states and non-NPT signatories (notably the de facto nuclear weapon states) have not. These latter states possess fissile material production facilities that are currently outside international safeguards. Verifying an FMCT will require measures ensuring that existing facilities are not used to produce materials for weapons. Part of this process will involve placing currently unsafeguarded facilities under international verification. In addition, the FMCT must be able to verify that clandestine facilities are not constructed to produce fissile materials for weapons.

Attempts to negotiate a fissile material cutoff agreement have a long and unsuccessful history (see Appendix 1), but conditions became more favorable following the end of the Cold War. Since then, France, Russia, the United Kingdom, and the United States have formally announced the end of fissile-material production for weapons purposes. China has also indicated that it has stopped producing materials for weapons.

These actions have been accompanied by numerous calls for a formal, multilateral cutoff treaty.[11] In 1993, the U.N. General Assembly endorsed a "nondiscriminatory, multilateral and . . . internationally and effectively verifiable" cutoff treaty to be negotiated at the Conference on Disarmament (CD) in

Geneva.[12] Efforts to reach consensus on a mandate to negotiate the treaty achieved success in 1995 in the form of a compromise brokered by then–Canadian CD Amb. Gerald Shannon. The Shannon Report noted that CD members could agree on a mandate to negotiate a treaty banning the *production* of fissile materials for weapons if the mandate "does not preclude any delegation from *raising for consideration*" the question of existing fissile material stocks (*emphasis added*).[13] (See Appendix 2.)

After the Shannon Report was issued, momentum to negotiate a treaty quickly stalled. Pakistan, Egypt, and others interpreted the Shannon Report as meaning that the FMCT talks should explicitly include existing stocks, while India, followed by a number of non-aligned states, linked the cutoff talks to multilateral talks on nuclear disarmament within a time-bound framework. With the exception of China, the nuclear weapon states, their key allies, and other CD members opposed these proposals. For more than three years after the Shannon Report was filed, efforts to start the talks went nowhere.

The May 1998 nuclear tests by India and Pakistan helped sweep away this logjam. Immediately following its first tests on May 11, India dropped its linkage between an FMCT and talks on nuclear disarmament, stating simply that it would be "happy to participate" in the proposed talks.[14] Pakistan initially hardened its position against the cutoff, describing proposals to begin negotiations as "irrelevant" in light of India's tests.[15] Pakistan then conducted its own tests at the end of May, which were followed by international calls for both India and Pakistan to join the cutoff talks (among other steps) to help reduce tensions on the subcontinent. Pakistan subsequently reversed itself and announced at the end of July that it supported the start of negotiations. On August 11, following intense U.S. pressure on Israel not to block consensus, the CD formally decided to form an ad hoc committee to negotiate the treaty on the basis of the Shannon Report. (See Appendix 3.)

With negotiations set to begin in 1999, the CD will have to overcome many tough obstacles before a treaty is concluded.

One of the most difficult will concern verification questions, especially about the level of verification needed in the nuclear weapon states. In addition, the issue of existing stocks remains unsettled, and is expected to occupy the ad hoc committee once the talks are in full swing.

The question of existing stocks is likely to come up in three contexts. First, there is the question of possible asymmetric stocks in South Asia. Pakistan would like to place international controls on India's plutonium stockpile, and has already asserted that it will use the talks to "seek a solution to the problem of unequal stockpiles."[16] India opposes negotiations on existing stocks.

Similarly, Egypt is expected to press for controls on Israel's stockpile. Israel, which hesitated to allow the talks to begin, finally said that it would not block the talks, but

Department of Energy, courtesy of Robert S. Norris, Natural Resources Defense Council.

The "H" Canyon Reprocessing Plant at Savannah River, South Carolina, once recovered fissile material from spent fuel; parts of the plant now support cleanup and disposition missions. If a cutoff treaty is signed, the plant likely will be subject to verification.

refused to take "a position towards finalizing the treaty or its contents."[17] An Israeli statement noted further the expectation that it will be "years before all of the participating countries reach an agreed upon treaty."[18] Absent significant progress in the Middle East peace process, Israel will oppose any provisions related to existing stocks.

The second context concerns existing military stocks in the five nuclear weapon states. While the United States and Russia have declared portions of their stocks to be excess, neither favors opening up decisions about how to treat existing stocks in a multilateral forum. As for the smaller nuclear weapon states, only the United Kingdom has declared any material to be excess, and like France, opposes any treatment of existing stocks in the FMCT negotiations. China is generally believed to oppose including military stocks in the talks. Nonetheless, key non-nuclear weapon states argue that unless stocks in the weapon states are dealt with in some way, the FMCT will have little credibility.

States like Japan fear the talks could include a production cutoff of separated plutonium for civil power programs.

The third context concerns civil stocks of fissile materials, especially plutonium stocks. It is unclear if Russia would allow the FMCT talks to cover its large stock of civil plutonium. States possessing large quantities of safeguarded civil fissile materials, notably Japan, fear that the talks could include a production cutoff of separated plutonium for civil power programs.

How the CD will address the stocks issue is unknown. Canada has proposed that the FMCT negotiations take the question of existing stocks into account as the negotiations on the cutoff "progress."[19] If CD members adopt this view, then it may be that the ad hoc committee negotiating the FMCT will form a "sub-group" to "take the views" of members on how the ad hoc committee might formally address existing stocks.

The question of existing stocks may be dealt with in another manner. The CD could endorse a separate, parallel process by

which existing stocks could be addressed separately. Several proposals were offered in 1998 to form an ad hoc committee that would, in the words of one such proposal, "deliberate upon the practical steps for systematic and progressive efforts to eliminate nuclear weapons as well as to identify if and when one or more such steps should be the subject of negotiations."[20] The question of existing stocks might emerge as one such step.

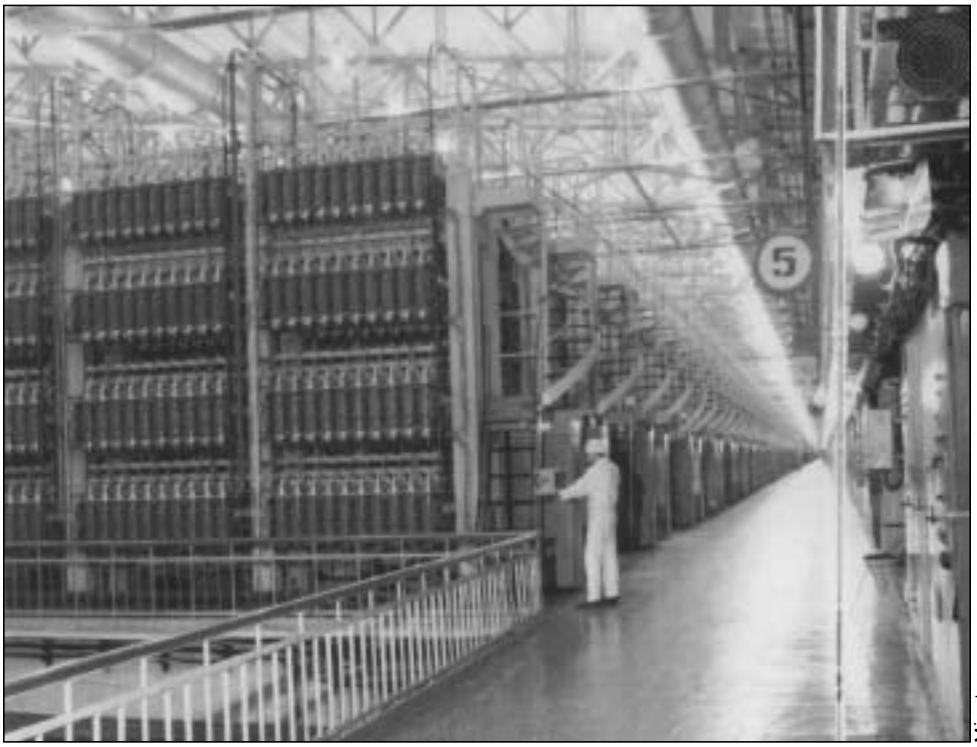
The CD might also endorse a wholly independent effort to address existing stocks. As discussed in Chapter II, this effort could build on existing U.S. and Russian efforts to make their stocks more transparent and to place these materials under international controls. Such an agreement or collection of agreements could be adhered to by the smaller nuclear weapon states and the de facto nuclear weapon states at some point in the future.

In any case, efforts to address existing stocks will be complicated and require careful consideration. A misstep could significantly delay the negotiation of the underlying cutoff.

Declaring Excess Materials and Placing Them under International Control

Making arms reductions "irreversible" will require international verification that materials removed from military stockpiles are not used for weapons. So far, the steps the nuclear weapon states have taken to declare excess materials and place them under international control have been inadequate.

The United States and Russia possess far more fissile materials than needed to sustain current or planned nuclear force structures. Approximately 75 percent of Russian and U.S. military fissile material stocks are currently outside weapons.[21] While both have declared portions of their stocks to be excess, these "declared" amounts are far less than their actual excess stocks under reasonable assumptions (see Table 2.1, page 31). Only a small portion of the declared excess materials have been placed under international controls, despite pledges by the United States and Russia to do so "as soon as it is practicable."[22]



Minatom

The Soviet Union produced 1,000 tonnes of highly enriched uranium, much of it at the Sverdlovsk centrifuge enrichment plant. Russia has agreed to blend down 500 tonnes of HEU to LEU for commercial sale.

The United States has formally declared 226 tonnes (metric tons) of fissile material to be excess to military needs, including approximately 175 tonnes of HEU and 50 tonnes of plutonium of various grades (see Table 1.4, page 14).[23] The vast majority of material declared excess so far is in impure forms—spent fuels, scraps, wastes, in-process solutions, and residues. The U.S. military has resisted declaring additional materials to be excess. At the U.S. Navy's insistence, much of the weapon-grade HEU outside weapons has been set aside for future use in propulsion reactors, and thus not declared excess.

While only a small fraction of these materials have been placed under international controls, arrangements are presently being made to increase this quantity (see Appendix 4). The United States has placed approximately two tonnes of plutonium and 10 tonnes of HEU under voluntary IAEA safeguards. In 1997, the United States offered to place an additional 15 tonnes of plutonium (weapon- and non-weapon grade) under voluntary safeguards or some other form of international con-

trols at an unspecified date. An additional 13 tonnes of HEU has been blended down to low-enriched uranium (LEU) for commercial sale, with the blending of the final 3.5 tonnes of this material verified by the IAEA. An additional 50 tonnes of HEU will be made available for safeguards over the next several years as they are blended down. The remaining plutonium and HEU, about half of which are currently in classified forms, await decisions on their final conversion to commercial products such as reactor fuel, or their disposition as waste before being placed under safeguards. Even under the most optimistic schedules, these programs will not be implemented until after 2005.

Russia has declared, at least in theory, the largest amount of fissile material to be excess. And it appears that Russia has not included scrap materials in its declared excess stocks. Rather, it has defined its excess stocks to include only materials from dismantled weapons. At the September 1997 IAEA General Conference, Russia announced "the decision to remove gradually from military programs up to 500 tonnes of highly enriched uranium and up to 50 tonnes of plutonium which has become available through the nuclear disarmament process."[24] Like the United States, Russia has linked controls to storage and disposition programs, which are expected to take many years to complete. Under a 20-year agreement, the United States is purchasing LEU created by blending down 500 tonnes of excess Russian HEU with slightly enriched uranium. Russian plutonium is to be placed in a storage facility at Mayak, which is now under construction with U.S. Defense Department assistance and funding.

The United Kingdom recently declared portions of its military fissile material stocks to be excess. Following the completion of its long-awaited Strategic Defense Review, Britain declared that 4.4 tonnes of plutonium, including 0.3 tonnes of weapon-grade plutonium, were excess and would be placed under Euratom safeguards. Britain has not declared any of its HEU to be excess, reserving its potential excess for naval propulsion purposes.

The United States and Russia are negotiating arrangements to place excess materials, particularly plutonium, under international controls. Under the "Trilateral Initiative" begun in September 1996, the United States, Russia, and the IAEA are seeking to "define the verification measures that could be applied at Russia's Mayak fissile material storage facility . . . and at one or more U.S. facilities" where excess "weapon-origin fissile materials" will be stored.[25] Special procedures are needed to prevent the disclosure of sensitive information about these materials to inspectors. These procedures will require the United States and Russia to verify bilaterally that the materials originated from nuclear weapons or weapons components, while allowing the IAEA to draw "independent and meaningful conclusions . . . that weapon-origin fissile materials submitted for verification remain removed from use in nuclear weapons programs."[26]

Given the intense secrecy that surrounds military fissile materials in both the United States and Russia, it is not surprising that the Trilateral Initiative has moved very slowly. After two years of conceptual development, the three parties are only beginning to test prototype equipment. The parties also need to develop the different verification approaches to be applied at specific facilities where excess fissile materials would be stored.

The initiative has been criticized by some non-weapon states who will have to pay to implement controls in the United States and Russia. These states want Russia and the United States to declare much larger quantities of materials to be excess or to place greater quantities of materials under IAEA verification before they are prepared to make large expenditures. At the September 1998 IAEA General Conference, the parties to the Trilateral Initiative announced their intention of developing a model verification agreement. This agreement would allow either Russia or the United States to submit additional, non-weapons-origin fissile materials to IAEA verification until these materials were judged to be no longer suitable for weapons purposes. As other nuclear weapon states begin to declare portions

of their stocks to be excess to military needs, the IAEA hopes other states could use this model agreement to make similar arrangements with the IAEA.

Efforts to place materials under international controls are further complicated by U.S. insistence that the Mayak facility be open to U.S. inspectors, regardless of the Trilateral Initiative's outcome. The U.S. Congress has linked continued funding for Mayak's construction to procedures that would allow U.S. inspectors to verify that materials entering the facility actually came from dismantled nuclear weapons and that these materials are not returned to weapons once they have been placed in the facility. So far, the United States has refused to consider reciprocal inspections of U.S. storage facilities at Pantex, where U.S. nuclear weapons are dismantled. Many believe that Russia will insist on reciprocity and not give in to a perceived U.S. ultimatum.

Disposition of Excess U.S. and Russian HEU and Plutonium

Excess fissile materials must be disposed in a manner that minimizes the risk that they can be reused or stolen. Making HEU benign is relatively straightforward; it can be blended down by mixing it with LEU, depleted, or natural uranium until it is no longer suitable for nuclear explosives. Both Russia and the United States are blending down excess HEU in this way. Under a 20-year Purchase Agreement, the United States is paying Russia for the "enrichment component" of LEU derived from blending down 500 tonnes of weapon-grade HEU with slightly enriched uranium. (The "enrichment component" is the amount of separative work that would have gone into an equivalent amount of enriched uranium, as opposed to the uranium itself.) Approximately 36 tonnes of weapon-grade uranium, and thus presumably HEU from dismantled weapons, had been blended down and transferred to the United States by the end of 1997. In 1998, 24 tonnes were scheduled to be blended down,

and 30 tonnes per year are planned for 1999 through 2001, when the current schedule expires.

The United States is similarly blending down much of its own excess HEU. By mid-1998, 13 tonnes of HEU had been "downblended" at the Portsmouth Gaseous Diffusion Plant. The United States plans to transfer an additional 50 tonnes of HEU to the U.S. Enrichment Corporation (USEC) for downblending between 1998 and 2003, and it has agreed to transfer 38 tonnes to the Tennessee Valley Authority sometime early in the next decade. While disposition plans for the remaining excess HEU have not been finalized, it is expected that approximately 18 tonnes contained in spent fuel and other impure forms will be processed and disposed of as waste.

Although these HEU disposition programs are technically simple, they face significant financial obstacles. The HEU Purchase Agreement, which is the largest source of hard currency for the Russian Ministry of Atomic Energy (Minatom), is

The United States has blended down 13 tonnes of HEU at the Portsmouth Gaseous Diffusion Plant. The blending down of the final 3.5 tonnes was monitored by the IAEA.

Department of Energy, courtesy of Robert S. Norris, Natural Resources Defense Council.

especially vulnerable to price changes in the international uranium market. Upon privatization in July 1998, USEC, which acts as the U.S. Executive Agent for the Purchase Agreement, announced that it would sell more than 70 million pounds of its own uranium through 2005. USEC said that the sale would be made gradually, to avoid upsetting the uranium market. But with so much uranium on the market, Western companies negotiating to buy the Purchase Agreement's natural uranium "feed component" from Russia are seeking lower prices. (The "feed component" is the amount of natural uranium that would have gone into the production of an equivalent amount of LEU. Under the Purchase Agreement, the United States provides the feed component to Russia, which Russia must then turn around and sell.) As a result, Russia's Minister of Atomic Energy said in July that the HEU Purchase Agreement was "dramatically deteriorating."[27] Although the United States and Russia may yet resolve this crisis, it is indicative of the difficulties that the Purchase Agreement is likely to face in the future.[28]

Disposing of plutonium is far more difficult than disposing of HEU.

The HEU Purchase Agreement also will face a major obstacle when it comes time to renegotiate prices and transfer schedules beyond 2001, when the current schedules expire. As a private company, USEC has little economic incentive to pay a premium for goods and services from a competitor if it can provide them more cheaply itself. While an oversight committee formed by the U.S. government has the power to replace USEC as Executive Agent, it is uncertain if this committee will retain enough leverage to ensure USEC's cooperation when new prices are set.

Finding an acceptable plutonium disposition method is far more difficult. Plutonium poses a higher risk of radiation exposure than uranium, making it more problematic to store, process, and transport. Even if they meet strict environmental, safety, and health standards to protect against accidental exposures to workers and releases to the environment, facilities that

handle plutonium generate public opposition and controversy. Nor can plutonium from weapons be blended down to a lesser grade—all grades of plutonium can be used to make nuclear weapons. Therefore, stringent physical protection, safeguards, and accounting procedures must be followed to assure that plutonium scheduled for disposition is not lost, stolen, or diverted anywhere in the disposition process.

The United States and Russia have agreed that plutonium disposition technologies should meet the "spent-fuel standard," which would render military-origin plutonium as unattractive for use or diversion as the plutonium found in spent commercial nuclear fuel. Russia has stated a clear preference for disposing of its excess plutonium by mixing plutonium oxide with uranium oxide and burning the resulting mixed-oxide (MOX) fuel in both light-water power reactors and breeder reactors. Russia has identified several existing reactors where it might burn this fuel and has proposed building additional reactors if necessary, but it lacks a facility for converting plutonium to oxide and for fabricating MOX fuel.

Russia cannot afford to pay for the facilities needed to support a MOX disposition program, which ultimately may cost several billion dollars. Russia's persistent economic troubles have made it difficult to secure financial support, much of which is expected to come from Western governments or corporations. The most ambitious plans for building disposition facilities in Russia have been proposed by France and Germany, who in June 1998 agreed to proceed with their efforts to build a pilot-scale MOX production plant in Russia. These proposals have not been accompanied by the necessary financing arrangements.

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facility. In July 1998, the United States and Russia concluded a five-year agreement to engage in small-scale tests and demonstrations, proceeding to pilot-scale projects "as soon as practicable."[29] However, the construction of industrial-scale facilities for converting plutonium and producing MOX fuel is to be carried out in cooperation with France, Germany, and other Western states. According to a joint statement agreed to by Clinton and Yeltsin at their September 1998 summit, "the U.S. and Russia expect that the comprehensive effort for the management and disposition of this plutonium will be a broad-based and multilateral one."[30]

The U.S. disposition program faces many obstacles.

The United States is better prepared than Russia to pay for its own disposition program, and the process of identifying disposition technologies and facilities has begun. In January 1997, the United States adopted a "dual-track" disposition policy. On one track, the DOE would burn much of excess U.S. plutonium as MOX fuel in commercial power reactors. On the second track, known as the immobilization option, DOE intends to seal cans of plutonium ceramic inside large canisters filled with vitrified high-level waste. In 1998, DOE selected the Savannah River Site in South Carolina as the preferred site to construct a a pit disassembly and a MOX fuel fabrication plant to support the MOX program.[31] Plutonium immobilization would take place at Savannah River in existing and newly constructed facilities. Expected costs for constructing and operating these facilities, and for transporting plutonium from Pantex to Savannah River, are nearly $3 billion.[32] Neither track is expected to be ready to begin operations before the middle of the next decade. Final disposition under either option would involve placing the spent MOX fuel or vitrified material in a geologic repository.

Officially, the DOE is pursuing both technologies to maximize the chance that either (or both) will succeed. But current plans call for using both technologies to dispose of the excess plutonium inventory. DOE plans to immobilize approximately 17 tonnes of excess plutonium, comprised mainly of impure

scraps, solutions, and waste. DOE would commit the remaining 33 tonnes, most of which originated primarily from retired nuclear weapons, to the MOX disposition track.

Despite these plans, the U.S. disposition program faces many obstacles. Neither the MOX nor the immobilization track has been proven on an industrial scale in the United States. Both also must overcome significant legal, environmental, and licensing challenges before being implemented; even beginning construction of the needed pit disassembly, plutonium conversion, and MOX fabrication facilities will require controversial legislation and interagency licensing agreements. In addition, the decision to rely heavily on the MOX option has sparked a debate about the civil use of plutonium in the United States. Once the licensing process has been initiated, public opposition may also prevent or significantly delay licensing approval. Nuclear utilities may be discouraged from accepting MOX fuel for their reactors, even if the U.S. government provides cost incentives to take part in the program.

The fate of the U.S. MOX track has implications for Russia's disposition program. Russia argues that simply immobilizing weapon-grade plutonium in vitrified high-level waste is insufficient to prevent its reuse in the long term. At some point, the radioactivity generated by the high-level waste will decay, making it relatively easy to extract the weapon-grade plutonium and reuse it in weapons. Architects of the dual-track strategy warn that "there is good reason to think that Russia will not eliminate its plutonium stockpile at all if the United States implements only immobilization."[33] Paradoxically, the success of Russia's disposition program is key to implementing the U.S. program. A senior Energy Department official has said that "the administration will not construct new facilities for disposing of surplus U.S. plutonium unless there is significant progress with Russia on plans for plutonium disposition."[34]

Efforts by both the United States and Russia to dispose of their excess plutonium stocks are now at a crucial stage. At the September 1998 Moscow summit, Presidents Clinton and

Yeltsin pledged to seek an agreement that will "lay out the concrete steps for plutonium disposition and govern" future cooperation between their respective countries.[35] This agreement is to include the schedule for constructing disposition facilities in both countries, international verification and transparency measures, safety and environmental protection provisions, physical protection and material control and accounting procedures, and financial arrangements.

Rather ambitiously, Clinton and Yeltsin signaled their intent to conclude the agreement by the end of 1998, a timetable that many thought was unrealistic and has not been met. Even if the two sides can agree on the technical details of the agreement, financial arrangements are far from certain. In October 1998 the United States Congress approved $200 million to support this effort, but Russia's increasing economic and political instability cloud chances for receiving badly needed financial commitments from other Western countries. Unless arrangements can be worked out for Russia's disposition program, the U.S. program may also be jeopardized.

Verifying Warhead Dismantlement

As nuclear arms reductions take effect, both Russia and the United States will require assurances that warheads are not being stored away for future redeployment. Under the March 1997 framework agreement for START III negotiations, the United States and Russia agreed that START III would "include measures relating to . . . the destruction of strategic nuclear warheads."[36] This is the first time that nuclear arms reductions would include the actual destruction of warheads.

Following up on the Helsinki statement, the United States initiated a technical review to assess verification options at Pantex.[37] The United States and Russia have also initiated joint projects to work out the techniques needed to verify the warhead dismantlement process. Under one effort, Sandia National Laboratory and Arzamas-16, Russia's premier nuclear weapons laboratory, are remotely monitoring warhead component stor-

age containers via the Internet.[38] However, formal negotiations are not expected to occur until START III talks begin.

The lack of negotiations on a warhead dismantlement regime is disappointing. Rapidly concluding a verifiable warhead dismantlement agreement is essential, since the longer it takes to negotiate and implement the agreement, the less useful it will be. The United States has dismantled more than 12,000 nuclear warheads since 1989, and another 1,800 warheads are scheduled to be dismantled by the end of the decade.[39] Russia is believed to be dismantling warheads at a similar rate. If the START III transparency arrangements are narrowly defined or take too long to finalize, few warheads will be left to verifiably dismantle.

Although incomplete, a U.S.-Russian agreement to verifiably dismantle nuclear warheads would establish a "warhead dismantlement norm" that ultimately could be applied to the three smaller weapon states and the de facto nuclear weapon states. There is a great need for such a norm. After South Africa announced that it had dismantled its secret nuclear arsenal, a controversy arose over the number of its weapons, including the question of whether South Africa might have retained one or more weapons.[40] A model verification regime could help prevent future controversies as other states give up their nuclear weapons, and it should be especially useful in the Middle East, where the formation of a regional nuclear-weapons-free zone would require Israel to dismantle its presumed nuclear arsenal.

Improving Safeguards

Under the NPT, the non-weapon states voluntarily accept "full-scope" IAEA safeguards on their nuclear programs to assure that nuclear materials are not diverted from peaceful to military use. The traditional mission of IAEA safeguards has been to verify the "correctness" of a state's declared nuclear activities by inspecting nuclear materials at a declared list of facilities and other locations. Under the old model safeguards agreement, known as INFCIRC/153, the IAEA had access only

to "strategic points" within these declared facilities, although inspectors could ask limited questions about other activities at a site. They could inspect other areas within a facility, or visit other buildings or facilities at a site only if invited to do so. While INFCIRC/153 also permitted "special inspections," this power was largely ignored and difficult to implement.

The safeguards could be easily evaded, as Iraq's nuclear weapons program revealed. Iraq conducted clandestine nuclear weapons activities at declared sites, and established separate, undeclared facilities that IAEA inspectors never learned about. Following the Gulf War and revelations about Iraq's nuclear program, the IAEA initiated an effort to strengthen safeguards. "Programme 93+2," as the effort became known, led the IAEA to expand it's legal authority and technical capability to gather more information about a country's nuclear program and to detect undeclared activities. As a former senior IAEA safeguards official said, ensuring that "material declarations are correct *and* complete is at the core of strengthened safeguards."[41]

Some of Programme 93+2's provisions were adopted in June 1995, when the IAEA Board of Governors found that they fell within the existing legal framework of INFCIRC/153. Under these so-called "Part I" measures, states are obligated to provide the IAEA with more detailed information about their nuclear infrastructure, including design information, information about past nuclear activities, and plans for future facility expansions. The Board also authorized safeguards inspectors to take environmental samples from strategic points within declared sites and to leave remote monitoring equipment at certain facilities. The Board also approved regular, no-notice inspections at strategic points in declared facilities, making it riskier for facility operators to conceal or camouflage undeclared activities at these locations.

The IAEA's review also sought to make safeguards more efficient and cost effective. For example, by taking advantage of no-notice or short-notice inspections, and by using remote monitoring equipment, the IAEA can conduct fewer regular

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Water sampling: here IAEA inspectors are testing techniques to detect very small quantities of plutonium or other elements that would indicate the production of separated plutonium.

inspections, particularly at nuclear power reactors. In this manner, the IAEA will be able to concentrate inspections on other fuel-cycle facilities. The IAEA expects that the savings generated by conducting fewer inspections will help offset the added costs associated with implementing more precise analytical measures, such as environmental monitoring. This cost savings is important because the safeguards budget operates under "zero-growth," a position insisted upon by the IAEA's members.

The IAEA began to implement Part I measures soon after their approval. In particular, IAEA inspectors began to collect swipe samples from "hot cells" to create a "baseline" against which future measurements from these facilities can be compared. Swipes also have been taken from enrichment plants. By the end of 1998, the IAEA collected swipe samples from 64 hot cell and uranium enrichment facilities.[42] The IAEA has also begun to deploy remote sensing equipment in Switzerland, and has begun to collect additional information from member states about decommissioned and closed facilities.

The IAEA Board determined that a new legal instrument was needed before implementing other provisions of the strength-

ened safeguards program. The IAEA convened a committee of 70 states to negotiate a "Model Protocol" to supplement the IAEA's existing safeguards authority. This protocol, approved in May 1997 after two years of negotiation, is codified as INFCIRC/540.

INFCIRC/540 greatly expands the IAEA's authority and technical capability to detect undeclared activities. It grants broad authority to IAEA inspectors to gather information, conduct inspections, and collect environmental samples. States must provide the IAEA with more detailed information about past, present, and planned nuclear activities, including information about nuclear-related research and development activities at sites that do not contain nuclear materials. States must also provide the IAEA with information about non-nuclear activities that support the nuclear fuel cycle, including certain manufacturing information and information about imports and exports of nuclear-related items.

INFCIRC/540 authorizes the IAEA to inspect any location within a declared site or location that contains nuclear material, and to take environmental samples from these sites for further analysis. States are also obligated to grant IAEA inspectors access to declared sites that do not contain nuclear material, as well as to closed or decommissioned nuclear sites. If the IAEA suspects that a state is conducting undeclared activities at a declared site or elsewhere, it may also take samples from other sites.

Significantly, INFCIRC/540 also anticipates future efforts to develop capabilities to detect undeclared activities at undeclared sites. A provision authorizes the IAEA Board of Governors to adopt wide-area environmental monitoring techniques without negotiating an additional legal instrument, should feasible and affordable techniques be developed.

The IAEA is now preparing to implement INFCIRC/540's provisions. In particular, it is establishing the necessary forms and procedures needed to support the strengthened safeguards program, such as creating guidelines for states to submit addi-

tional information, developing model subsidiary arrangements, and setting forth procedures for broader inspections.

However, the U.S. General Accounting Office has criticized the IAEA for not establishing either the criteria to determine the effectiveness of the strengthened safeguards program, or a long-term implementation plan with concrete milestones.[43] U.S. and IAEA safeguards officials responded to these criticisms by noting that the IAEA's attention was focused on concluding Model Protocols with the non-weapon states as quickly as possible.

Many key NPT members have already taken this step. As of September 1998, the IAEA Board of Governors had approved model protocols for 28 non-nuclear weapon states, including all 13 non-nuclear members of the European Union.[44] Australia, the Holy See, Jordan, and New Zealand have ratified Model Protocols, and Armenia and Georgia are tentatively implementing model provisions. Discussions between the IAEA and a number of other states are likely to result in the submission of Model Protocols to the IAEA Board by early 1999. Japan, South Korea, and South Africa are among the countries now negotiating with the IAEA. However, many states located in regions where proliferation is considered to be a threat, such as the Middle East, have yet to adopt protocols, much less submit them for acceptance by the IAEA Board of Governors.

1. This paper follows the conventions of the NPT in defining the status of different states' nuclear capabilities. As defined by the NPT, the term "nuclear weapon states" (or simply "weapon states") refers to the United States, Russia, the United Kingdom, France, and China—the five states that "manufactured and exploded a nuclear weapon or other nuclear explosive device prior to January 1, 1967." "Non-nuclear weapon states" (or "non-weapon states") refers to all other NPT members. The term "de facto nuclear weapon states" refers to India, Pakistan, and Israel, which are the three states outside the NPT with significant unsafeguarded nuclear facilities; Cuba is also outside the NPT but lacks significant facilities outside safeguards.
2. Hans Blix, "Future Directions of Nuclear Verification," *IAEA Bulletin*, vol. 39, no. 4, (December 1997), p. 37.

3. This section draws heavily on recommendations made in David Albright, Frans Berkhout, and William Walker, *Plutonium and Highly Enriched Uranium 1996: World Inventories, Capabilities, and Policies* (Oxford: Stockholm International Peace Research Institute [SIPRI] and Oxford University Press, 1997), especially pp. 6–8 and chapter 15.
4. "Guidelines for the Management of Plutonium," International Atomic Energy Agency, INFCIRC/549, March 16, 1998.
5. These declarations can be found in INFCIRC/549/Add. 1 (Japan); Add.2 (Germany); Add. 3 (Belgium); Add. 4 (Switzerland); Add. 5 (France); Add. 6 (United States); Add. 7 (China); Add. 8 (United Kingdom); and Add. 9 (Russia).
6. "John Battle Publishes National Civil Uranium Figures," UK Department of Trade and Industry, P/98/525, July 1, 1998.
7. Correspondence from Victor Reis, Assistant Secretary for Defense Programs, U.S. Department of Energy, to Kevin O'Neill, October 1, 1997.
8. Ibid.
9. "Joint Statement on Weapons Reductions," White House Office of the Press Secretary, reprinted in *Arms Control Today*, vol. 25, no. 5, (June 1995).
10. Ibid.
11. For example, President Clinton first endorsed a "multilateral convention prohibiting the production of HEU or plutonium for nuclear explosive purposes or outside of international safeguards" in September 1993; see "Fact Sheet: Nonproliferation and Export Control Policy," the White House Office of the Press Secretary, September 27, 1993. At the May 1995 NPT Review and Extension Conference, NPT members endorsed "the immediate commencement and early conclusion" of a FMCT as one of the "principles and objectives" of nonproliferation and disarmament; see NPT/CONF.1995/32/DEC.2 New York, 1995, para. 4(b).
12. U.N. General Assembly Resolution 48/75L, December 1993.
13. "Report of Amb. Gerald Shannon on Consultations on the Most Appropriate Arrangement to Negotiate a Treaty Banning the Production of Fissile Material for Nuclear Weapons or other Nuclear Explosive Devices," CD/1299, March 24, 1995.
14. Government of India, Statement by the Ministry of Foreign Affairs, May 11, 1998.
15. "Statement by Amb. Munir Akram to the Conference on Disarmament," May 28, 1998.
16. "Statement by Amb. Munir Akram to the Conference on Disarmament," July 30, 1998.
17. "PM Netanyahu's Remarks Regarding Media Reports Concerning Israel's Nuclear Policy," statement issued by the Prime Minister's Media Advisor, August 11, 1998.
18. Ibid.
19. "Working Paper with Regard to an Ad Hoc Committee on a Fissile Material Cutoff Treaty," Mission of Canada to the Conference on Disarmament, January 22, 1998.

20. "Statement by the Permanent Representative of the Republic of South Africa, H.E. Mr. J. S. Selebi to the Conference on Disarmament," January 20, 1998. Canada and Belgium have offered similar proposals.
21. See *Plutonium and Highly Enriched Uranium 1996*, especially p. 414, table 14.11.
22. "Moscow Nuclear Safety and Security Summit, Final Declaration," excerpted in *Disarmament Diplomacy*, Issue 5, (May 1996), p. 34.
23. About 33 tonnes of this excess HEU is weapon-grade. Excess U.S. plutonium includes 38 tonnes of weapon-grade plutonium, 13 tonnes of fuel-grade plutonium, and one tonne of reactor-grade plutonium. For more details, see *Plutonium and Highly Enriched Uranium*, especially p. 45, table 3.5, and p. 92, table 4.4.
24. "Letter from the President of the Russian Federation to the Participants at the 41st General Conference of the International Atomic Energy Agency," September 26, 1997.
25. "Press Statement on the Trilateral Initiative," IAEA Press Release PR 97/26, September 30, 1997.
26. "Statement on Behalf of the Russian Federation, the United States and the International Atomic Energy Agency," IAEA Press Release 98/18, September 22, 1998.
27. Unofficial translation of a letter from Yevgeny Adamov, Minister of Atomic Energy, to Sen. Pete Domenici, reprinted in Mike Knapik, "USEC Inc. Stock Begins Trading at $14.25; Timbers Backs HEU Deal, Healthy U Market," *Nuclear Fuel*, July 27, 1998.
28. For a thorough account of the HEU purchase agreement and the problems it must overcome, see Richard Falkenrath, "The HEU Deal," in Graham Allison et al., *Avoiding Nuclear Anarchy: Containing the Threat of Loose Russian Nuclear Weapons and Fissile Material* (Cambridge, Mass.: MIT Press, 1994), Appendix C.
29. "Agreement between the Government of the United States and the Government of the Russian Federation on Scientific and Technical Cooperation in the Management of Plutonium that has been Withdrawn from Nuclear Military Programs," White House Office of the Press Secretary, July 24, 1998.
30. "Joint Statement of Principles for Management and Disposition of Plutonium No Longer Required for Defense Purposes," White House Office of the Press Secretary, September 2, 1998.
31. "Richardson Certifies Safety, Security, Reliability of Nuclear Stockpile without Nuclear Testing: Makes Two Key National Security Decisions on Tritium and Pit Disassembly," *Department of Energy News*, R-98-200, December 22, 1998.
32. *Cost Analysis in Support of Site Selection for Surplus Weapons-Usable Plutonium Disposition*, Department of Energy, DOE/MD-0009 rev. 0, July 22, 1998; p. 3–17.
33. John Holdren, John Aherne, Richard Garwin, et al. "Excess Weapons Plutonium: How to Reduce a Clear and Present Danger," *Arms Control Today*, vol. 26, no. 9 (November/December, 1996), p. 4.

34. Statement of Howard Canter, Acting Director of the Office of Fissile Materials Disposition, U.S. Department of Energy, before the Committee on Armed Services, U.S. Senate, March 12, 1998.
35. "Fact Sheet: Plutonium Disposition Statement," the White House Office of the Press Secretary, September 2, 1998.
36. "Fact Sheet: Joint Statement on Parameters on Future Reductions in Nuclear Forces," the White House Office of the Press Secretary, March 21, 1997.
37. *Transparency and Verification Options: An Initial Analysis of Approaches for Monitoring Warhead Dismantlement*, Department of Energy, May 19, 1997. For a concise treatment of verifying warhead dismantlement, see Theodore Taylor, "Dismantlement and Fissile Material Disposal," in Frank von Hippel and Roald Sagdeev eds. *Reversing the Arms Race*, (New York: Gordon and Breach, 1990), ch. 5.
38. See http://magtomag.ca.sandia.gov to obtain real-time information about canisters stored at Sandia or Arzamas.
39. *"Transparency and Verification Options,"* p. 40.
40. For more details about these controversies, see David Albright's study on South Africa's nuclear weapons program (Washington, D.C.: Institute for Science and International Security, *forthcoming).*
41. Richard Hooper, "The Conclusion of Programme 93+2: A Status Report on Strengthened and More Efficient Safeguards," IAEA-SM-351/142. Paper prepared for Symposium on International Safeguards. (Vienna, International Atomic Energy Agency, October 13–17, 1997.)
42. "Nuclear Nonproliferation: Uncertainties with Implementing the IAEA's Strengthened Safeguards System," U.S. General Accounting Office, GAO/NSIAD/RCED-98-184 (July 1998); p.8.
43. Ibid.
44. These states are: Armenia, Australia, Austria, Belgium, Bulgaria, Canada, Croatia, Denmark, Finland, Georgia, Germany, Ghana, Greece, Holy See, Ireland, Italy, Jordan, Lithuania, Luxembourg, Netherlands, New Zealand, Philippines, Poland, Portugal, Spain, Sweden, Uzbekistan, and Uruguay. France, the United Kingdom, and the United States are also taking steps to partially implement INFCIRC/540.