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Eliminating Nuclear Warheads

More than 50,000 nuclear weapons may be decommissioned during the next 10 years. Their disposal requires both technical and political innovations

by Frank von Hippel, Marvin Miller, Harold Feiveson, Anatoli Diakov and Frans Berkhout

The U.S. and the former Soviet Union are making deep cuts in their cold war arsenals. In the long run, the elimination of tens of thousands of surplus nuclear weapons will greatly reduce the threat of nuclear war. In the short term, however, chaotic conditions in the former Soviet Union pose a danger that weapons or materials derived from them may find their way to renegade states or terrorist groups.

About 35,000 nuclear warheads are scattered across the territory of four of the nations that were born when the Soviet Union disintegrated late in 1991: Russia, Ukraine, Kazakhstan and Belarus. Political struggle persists within Russia, which inherited the largest part of the arsenal, as does friction between Russia and Ukraine, which inherited the second largest part.

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Some progress has been made in securing the surplus nuclear warheads. All Soviet tactical warheads deployed in the 14 non-Russian republics and most of those deployed in Russia have reportedly been withdrawn to storage sites within Russia, significantly reducing the risk of unauthorized use or theft.

In addition, the START I and START II agreements—signed in July 1991 and January 1993, respectively—would have the former Soviet Union and the U.S. reduce their strategic arsenals from roughly 10,000 warheads apiece today to less than 3,500 each by the year 2003. Under START I, Ukraine, Kazakhstan and Belarus have agreed to remove the approximately 3,000 strategic nuclear warheads that remain in their territories to Russia for dismantling and to join the Nonproliferation Treaty as nonnuclear weapons states. Belarus has ratified both treaties, but Kazakhstan has ratified only START I, and Ukraine has ratified neither. Moreover, Russian hardliners may oppose ratification of START II because it would eliminate multiple-warhead land-based missiles, the heart of the Russian strategic arsenal, while leaving U.S. submarine and bomber forces essentially intact.

Even if all these treaties are ratified, the problem of implementing them will remain. The unsettled political situation in Russia has put its nuclear complex under extraordinary stress. In December 1992 the head of the Russian nuclear-fuel reprocessing facility outside Chelyabinsk, where more than 25 tons of separated plutonium is stored, complained that his workers had not been paid in more than two months. Scientists in Russia's nuclear-weapons design laboratories were told earlier that year to plant potatoes if they wanted to be sure to have food for their families.

Transporting tens of thousands of decommissioned nuclear weapons to storage locations, dismantling them and disposing securely of their uranium and plutonium will be a daunting task, especially under the current circumstances. There are no confirmed reports that Soviet warheads or materials have been diverted, but it is imperative that arrangements be agreed on that will allow monitoring and assistance from the West.

Comparable security concerns do not exist today in the U.S. warhead elimination process. Nevertheless, political considerations require that monitoring be done on a reciprocal basis. Indeed, the U.S. Senate recognized this fact when it ratified START I in October 1992 and instructed the president to seek agreement on reciprocal inspections and other means to monitor the numbers of nuclear weapons in the stockpiles of the U.S. and the former Soviet Union. The Russian government has indicated that it would accept such reciprocal monitoring, but thus far the U.S. has focused on trying to negotiate unilateral U.S. monitoring of aspects of Russian warhead elimination.

This policy should be reconsidered. What progress has been made to date has been a result of U.S. willingness to make reciprocal concessions, such as the matching "unilateral" initiatives, an-

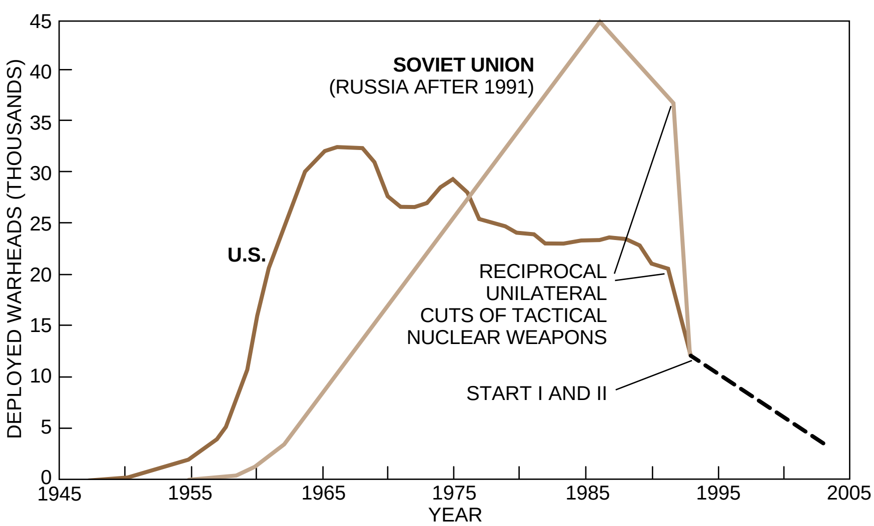
TACTICAL NUCLEAR WARHEAD from the former Soviet Union is loaded on board a truck in Ukraine for transport to Russia, where it is to be stored. The withdrawal of tactical warheads from service in 1992 eased nuclear tensions, but now the U.S. and the Soviet Union's successors must decide what to do with this warhead and tens of thousands more.

NUCLEAR WEAPONS of the former Soviet Union are scattered across the territory of four successor states. More than 3,000 remain in Ukraine, Kazakhstan and Belarus but should eventually be shipped to Russia for disposal. Warheads are currently being dismantled at four sites in Russia. Negotiations are under way to dilute at least 500 tons of the resulting highly enriched uranium with natural uranium and sell it to the U.S. for use as reactor fuel. Weapon-grade plutonium is still being separated from spent reactor fuel at facilities near Tomsk and Krasnoyarsk. A third plant, near Chelyabinsk, has separated more than 25 tons of civilian-grade plutonium from power-reactor fuel since 1978.

nounced in 1991 by President George Bush and Russian leader Mikhail S. Gorbachev, for decommissioning most Soviet and U.S. tactical warheads.

Although START I and START II will increase the scale of the warhead disposal problem, Russia and the U.S. are already dismantling nuclear warheads at a considerable rate—between 1,000 and 2,000 warheads a year in each country.

Taking a thermonuclear warhead apart safely is a technically demanding task. Most modern strategic warheads consist of a "primary" (fission) explosive and a thermonuclear (fusion) "secondary" that is ignited by the explosion of the primary. The hollow, spherical "pit" of the primary holds the warhead's plutonium, three to four kilograms on average, sometimes with some highly enriched uranium (that is, HEU, incorporating more than 90 percent chain-reacting uranium 235). The secondary generally also contains HEU, for a total of perhaps 15 kilograms for the average warhead. All told, surplus U.S. warheads contain about 50 tons of plutonium and up to 400 tons of HEU. Surplus Soviet warheads, including about 10,000 that have already been dismantled, contain about 100 tons of pluto-



SUPERPOWER ARSENALS have declined precipitously since 1991, when George Bush and Mikhail S. Gorbachev announced that most of their nations' tactical nuclear warheads would be placed in storage. Under current treaties, each nation is to reduce the number of strategic weapons deployed to between 3,000 and 3,500 by the year 2003. In the absence of further agreements, Russia and the U.S. will each retain a total of about 5,000 deployed strategic and tactical warheads. The agreements mandating these reductions, however, do not dictate what is to become of the warheads taken out of service or of the uranium and plutonium they contain.

nium and more than 500 tons of HEU.

When workers dismantle a warhead, they first remove the primary and secondary from the bomb casing and then detach the chemical explosives that surround the pit. Finally, they recover the plutonium and HEU for reuse or storage. In the U.S., disassembly takes place at the Department of Energy's Pantex facility near Amarillo, Tex. The secondaries go to the department's Y-12 plant in Oak Ridge, Tenn., where their uranium is recovered and stored.

Until 1989, U.S. pits went to the Energy Department's Rocky Flats plant near Denver, where their plutonium was recovered and purified for reuse. The plant was closed because of environmental and safety problems, however, and a replacement has yet to be built. In the meantime, pits are stored in sealed canisters in heavily protected bunkers at Pantex. There are 60 of these so-called igloos, each with room for up to about 400 pits, which is more than sufficient to accommodate the pits from all the U.S. warheads currently scheduled to be taken out of service.

In Russia, warheads are being dismantled at four sites with a reported combined disassembly capacity of up to 6,000 warheads a year. The Russian Ministry of Atomic Energy has asked for U.S. assistance to construct a secure central store for 40,000 containers for nuclear warhead components or materials near the Siberian city of Tomsk, one of Russia's three plutonium production centers. The Tomsk city government has opposed the plan because of concern about potential plutonium hazards. After the explosion that destroyed part of the nearby Tomsk-7 reprocessing plant this past April, the proposal was officially "deferred."

Whatever the fate of this facility, secure storage of nuclear materials is the most critical near-term objective for both Russia and the U.S. Such storage would protect materials until they can be processed into more proliferation-resistant forms. So long as the recovered nuclear materials remain in forms easily converted back to weapons, their existence will erode confidence in the disarmament process and raise dangers of diversion to nonnuclear nations or terrorists.

The obvious way to render highly enriched uranium useless for weapons is to blend it with large quantities of the non-chain-reacting uranium isotope, uranium 238, which makes up 99.3 percent of natural uranium. Reconstituting the enriched fraction requires isotope separation techniques, which have been mastered by only a few countries. If the HEU is diluted to about 4 percent uranium 235, the resulting "low-enriched" uranium can be used to fuel standard light-water nuclear power reactors.

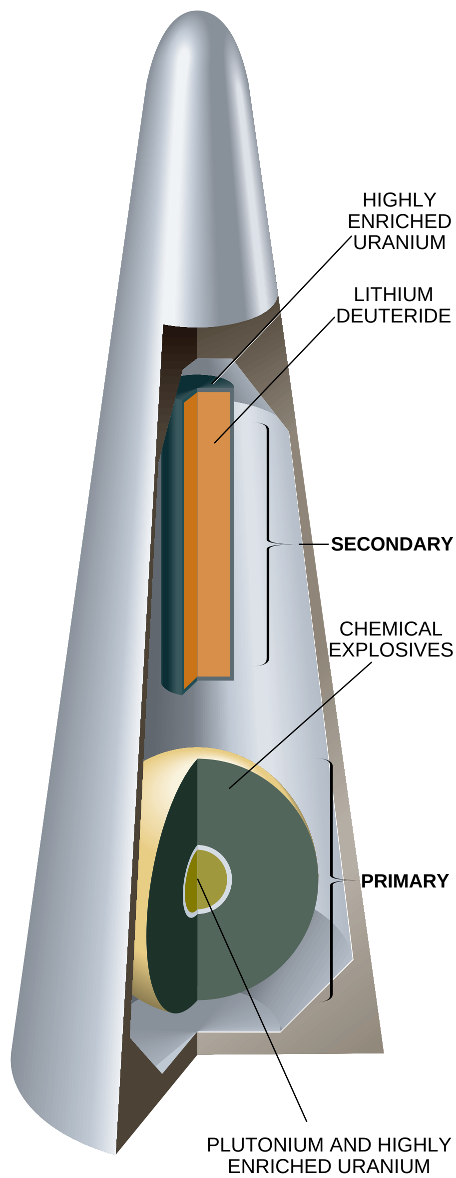
Indeed, following a suggestion by Thomas Neff of the Massachusetts Institute of Technology, the U.S. government has agreed to pay roughly $10 billion for low-enriched uranium derived from about 500 tons of weapon-grade uranium recovered from surplus Soviet warheads. This quantity could fuel about one eighth of the world's nuclear capacity during the 20-year period covered by the contract. According to present plans, the Russians will dilute the HEU in a facility near Ekaterinburg (formerly Sverdlovsk) before shipment to the U.S.

About 400 of the approximately 500 tons of weapons uranium in the U.S. stockpile will probably also become surplus. A few tons a year will be used to fuel nuclear-powered warships and submarines, as well as reactors devoted to research or to making radioisotopes for medical and other uses. The rest should be diluted down to low enrichment levels as quickly as possible and held for eventual sale as power-reactor fuel. This action would reduce the cost of safeguarding the material and would also reassure Russia and other countries that U.S. arms reductions are irreversible.

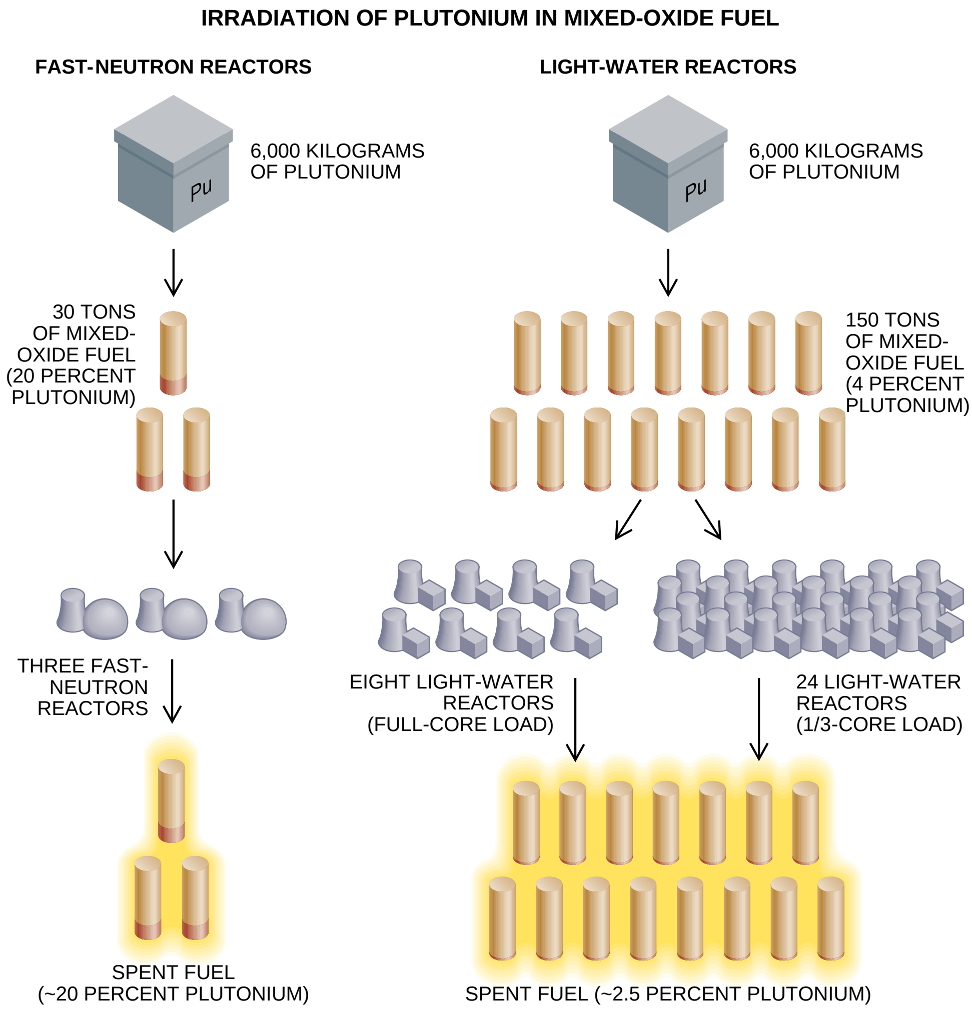
The 150 tons of surplus plutonium that dismantled warheads will yield poses a thornier problem because it cannot be denatured isotopically in the same way as weapons uranium. But reclaiming plutonium for reuse in weapons can be made much more difficult by mixing it with radioactive fission products. One obvious way to do this is to substitute the weapons plutonium for uranium 235 in so-called mixed-oxide fuel that can be used in commercial light-water reactors. Three years in a reactor core would reduce the amount of plutonium in the fuel by about 40 percent.

The plutonium remaining in the discharged spent fuel would have an increased fraction of plutonium isotopes other than plutonium 239 (the preferred isotope for warheads), making it less attractive as a weapons material. This reactor-grade plutonium, however, could still be separated and used to make simple bombs having yields of about 1,000 tons of high explosive. (To put this in perspective, the bomb that recently wreaked such havoc at the World Trade Center in New York City contained about half a ton of high explosive.)

Japan and some Western European nations have already set up a partial infrastructure for recycling plutonium recovered from spent power-reactor fuel, so the addition of weapons plutonium to this system might seem attractive. Unfortunately, the electric utilities in these countries have no interest in pursuing this option. The cost of manufacturing mixed-oxide fuel is currently considerably greater than the cost of low-enriched uranium fuel, and in any case, these nations already anticipate a significant surplus of civilian plutonium.



NUCLEAR WARHEAD typically consists of a fission "primary" and a fusion-fission "secondary." When weapons are dismantled, their chemical explosives are detached; the plutonium of the primary and the highly enriched uranium of the secondary are then removed for processing.



PLUTONIUM DISPOSAL is a problem that has yet to be definitively solved. Two solutions have been proposed. One would employ plutonium to fuel nuclear reactors, irradiating it and reducing its value for weapons. The other, safer and less costly, would incorporate the metal in glass "logs" soon to be manufactured for storing high-level radioactive waste.

Furthermore, mixed-oxide fuel raises serious security concerns because the freshly manufactured material contains plutonium in a readily separable form, unaccompanied by fission products. Such concerns led the U.S. to reject commercial plutonium recycling more than a decade ago. As a result, the U.S. has no facility for making mixed-oxide, light-water reactor fuel.

Russia also has no mixed-oxide fuel fabrication plant. Even if it did, the rate at which the plutonium could be irradiated in Russian light-water reactors would be very limited. Plutonium's nuclear characteristics limit the fraction of mixed-oxide fuel that can be substituted for low-enriched uranium in most light-water reactors to about one third of the core. Consequently, a 1,000-megawatt electric light-water reactor could process only about 300 kilograms of weapons plutonium a year. Russia has seven such reactors operating, with another nearly complete, and so could irradiate about 2.5 tons of plutonium a year. At this rate, it would take 40 years to irradiate Russia's 100 tons of surplus weapons plutonium. During this entire period, the plutonium in Russian fuel fabrication plants and in transit to power-reactor sites would be susceptible to diversion.

Security risks could be reduced by building reactors, designed to accept full cores of mixed-oxide fuel, at a single highly secured site in each country. Various reactor types have been proposed for this purpose. The one that could probably be built most quickly is a light-water reactor manufactured by ABB Combustion Engineering, which was specifically designed to be easily adaptable to a full plutonium core.

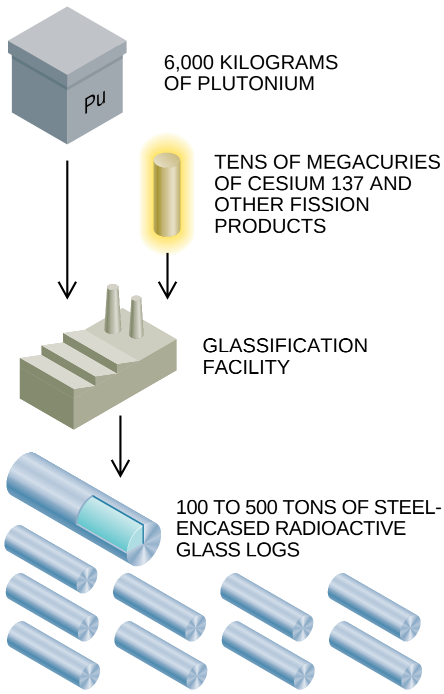
Other candidates include the liquid metal–cooled fast-neutron reactor and the high-temperature gas-cooled reactor; advanced versions of these concepts are under development in the U.S. and other countries. The fast-neutron reactor can irradiate more plutonium than can a light-water reactor of equivalent power because of the higher percentage of plutonium in the fuel. Unfortunately, without recycling, the plutonium in the spent fuel would still be near weapon grade. The gas-cooled reactor, in contrast, could irradiate plutonium to a point where most of it would be destroyed and the remainder rendered even more undesirable for weapons than the plutonium in spent fuel from a light-water reactor. Yet it makes little sense to pursue virtually complete fission of military plutonium in the absence of plans to treat similarly the much larger quantities of civilian plutonium (more than 1,000 tons by the turn of the century) now accumulating in unreprocessed power-reactor fuel.

Moreover, both the liquid metal–cooled and gas-cooled reactors require considerable development and demonstration before they can be considered ready for full-scale implementation. (This is even more true of another proposed route to plutonium elimination: irradiation by neutrons produced in targets bombarded by protons accelerated to high energies.) The cost would be several billion dollars and at least a decade of delay. And once the technology had been demonstrated, there would still be costly production facilities to build.

Given these difficulties, researchers in the U.S. and Russia are considering alternatives that could possibly be implemented more rapidly and cheaply. In particular, we and others have been examining the feasibility of disposing of plutonium together with radioactive waste. Facilities have already been constructed in both countries, as well as in France, Britain and Belgium, to dispose of high-level reprocessing waste by incorporating it into glass that will eventually be placed in deep geologic repositories. Although disposal of plutonium with radioactive waste would forgo the electricity it could generate, this loss is insignificant in the larger context. At present uranium and plutonium prices, plutonium will not be an economic fuel for at least several decades. In addition, one or two hundred tons of the metal could power the world's current nuclear capacity for only a fraction of a year.

The security threat posed by this material should therefore take precedence. Direct disposal of plutonium would involve much less handling and transport—and so less risk of diversion—than would its use in fuel. If the use of

MIXING OF PLUTONIUM WITH HIGH-LEVEL RADIOACTIVE WASTE



plutonium for reactor fuel proves economically and politically viable at some future time, there will still be thousands of tons of civilian plutonium recoverable from spent fuel.

A waste glassification plant has been built in Aiken, S.C., the site of the now defunct Savannah River military plutonium production complex. Between 1994 and 2009 this facility is expected to produce at least 8,000 tons of radioactive glass in the form of massive steel-sheathed "logs" three meters long and 0.6 meter in diameter, each containing about half a ton of high-level waste slurry mixed with 1.2 tons of borosilicate glass. Seventy tons of plutonium could be dissolved in these logs without raising the concentration to levels above those in spent power-reactor fuel.

It would take at least five years to complete the safety assessments and other preparations required for incorporating weapons plutonium into radioactive glass at Savannah River, but experts there have not identified any significant technical obstacles. Because the glass would be made in any case, the extra costs involved are those related to the preprocessing of the plutonium and its introduction into the melter and for appropriate safeguards and security arrangements. These costs would probably be less than those of irradiating plutonium in light-water reactors.

Although embedding the weapons plutonium in radioactive glass means that it would remain weapon grade, the highly radioactive fission products would make it at least as difficult to recover the plutonium from the glass logs as from spent fuel. The plutonium would be inaccessible to subnational groups, and even a determined country would need considerable time and resources to recover it.

Another possibility is to put the plutonium into logs without high-level waste, instead adding elements, such as gadolinium, that are very similar chemically to plutonium and thus difficult to separate from it. This strategy would make the plutonium inaccessible to subnational groups, even though a would-be nuclear nation could still recover it relatively easily. The plutonium-dilutant mixture could also be "spiked" with cesium 137, a fission product that is an intense gamma emitter and has a 30-year half-life.

Russia is glassifying high-level waste at its reprocessing site near Chelyabinsk. About as much waste resides in the Chelyabinsk tanks (measured in terms of its radioactivity) as at Savannah River, but the phosphate glass used at Chelyabinsk does not appear to be as durable as the borosilicate glass used in Western Europe, Japan and the U.S., nor does it have the safety advantages associated with the neutron-absorbing boron.

If borosilicate glassification technology were transferred to Russia, its weapons plutonium could easily be embedded in such glass. Unfortunately, the Russian nuclear establishment has shown little enthusiasm for glassification or, more generally, for processing plutonium into more diversion-resistant forms. This material was produced at enormous human and environmental cost; Russian nuclear officials consider it a national heritage. They prefer to store it for possible future use, even though safeguarding it for decades will be expensive and risky. A recognition of these costs and risks by the Russian political authorities, together with financial incentives and the knowledge that the U.S. is willing to render its own weapons plutonium inaccessible, may convince Russia to abandon its deadly treasure.

Assuming that the U.S. and former Soviet states can come to an agreement on how to dispose of surplus warheads, there is still the question of verification. International confidence in the nuclear-arms reduction process would be enhanced if disposal of surplus warheads could be subjected to outside monitoring. Moreover, experts at Los Alamos National Laboratory and at Pantex have concluded that effective monitoring could be carried out without revealing sensitive nuclear-warhead design information. Nevertheless, the U.S. government continues to pursue an essentially unilateral policy by limiting itself to the monitoring rights it can negotiate in connection with purchases of Soviet highly enriched uranium and assistance in building storage facilities for surplus weapons.

In addition, we believe the U.S. and Russia should conduct such monitoring on a bilateral basis through the warhead dismantlement stage, putting recovered uranium and plutonium under international safeguards after they have been processed to remove weapons design information. The International Atomic Energy Agency has already offered to monitor the storage and subsequent use or disposal of the surplus warhead materials. This combination of bilateral and international safeguards would help ensure that the dismantlement process was secure and that the nuclear materials would never be reused in weapons.

Russia's current leadership has indicated that it is agreeable to such comprehensive monitoring—if it is done on a reciprocal basis. It is not clear how long this window of opportunity will stay open. The U.S. should move quickly to offer Russia a reciprocal right to monitor U.S. warhead elimination. Ultimately, these steps should be reinforced by a strengthened nonproliferation regime in which production of weapons-usable materials is ended worldwide, not just in the U.S. and the former Soviet Union. Such a production ban would assure that reductions in existing nuclear arsenals are irreversible and would minimize the risk that other nations or terrorist groups will acquire the wherewithal to make nuclear weapons.

FURTHER READING

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