Disposition of Fissile Material from Nuclear Weapons

by

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Presented
at
The Sixth
ISODARCO-Beijing Seminar on Arms Control

October 28-November 2, 1998

Shanghai, China

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Introduction

The United States and Russia have now both agreed that each country will dispose of limited amounts of plutonium and highly-enriched uranium (HEU) declared to be in excess of military needs. Below we review the status of these programs.

Declarations of Excess Fissile Material by the United States

Excess Highly-Enriched Uranium. In 1996 the United States declared that 174.3 tonnes (t) of highly-enriched uranium (HEU) were in excess of military requirements (Table 1).[1] Approximately one-half of this was in metal or oxide form and reserved for weapons. The other half was from a variety of sources, including irradiated reactor fuel, uranium hexafluoride (UF_6) which was to be converted into naval reactor fuel but did not meet reactor fuel specifications, and uranium, chemically separated from spent production reactor fuel, containing a high concentration of uranium-236. Moreover, at least 98 t of the total has an average enrichment of approximately 40% U-235, so the 174.3 t HEU total is actually equivalent to less than 115 t of 93.5%-enriched HEU.

The United States announced in June 27, 1994, that it had produced 994 t of HEU between 1945 and 1992. This total includes HEU produced for nuclear weapons and fuel for naval reactors and civil research and test reactors. The U.S. Department of Energy (DOE) announced its intention to provide an analysis of how the total, now estimated to be a little over 1000 t of HEU, was utilized. To date, however, no breakdown has been provided to indicate what fraction of the approximately 1000 t was produced for weapons. A reasonable assumption is that 50-75 percent was in weapons or available for weapons.

Excess Plutonium. In February 1996, the United States declared that the government had an inventory of 99.5 t of plutonium as of September 30, 1994.[2] Not included in this inventory is approximately 350 t of plutonium locked away in some 38,600 t of U.S. commercial reactor spent fuel.[3] The U.S. declaration that 52.5 t is in excess of military needs suggests that the U.S. government is disposing of about one-half of its weapons plutonium. Actually as seen from Table 2, only 38.2 t of the declared excess was weapon-grade plutonium (WGPu), and of this only 22.7 t represents plutonium that was at the time in the form of plutonium warhead components, called plutonium "pits." The 29.8 t of plutonium not in pits includes the plutonium that was in "pipeline" and waste materials remaining when pit manufacturing was halted at the Rocky Flats plant in 1989, and in fresh and spent reactor fuel, waste materials and other forms at other DOE sites.

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[1] Uranium is considered to be "highly-enriched" provided the weight concentration of uranium-235 in the uranium is equal to, or exceeds, 20 percent.

[2] U.S. Department of Energy, "Plutonium: The First Fifty Years," February 1996.

[3] U.S. Department of Energy, "Integrated Data Base Report—U.S. Spent Nuclear Fuel and Radioactive Waste Inventories, Projections, and Characteristics," DOE/RW-0006, Rev. 13, December 1997, p. 1-7; spent fuel inventory projected as of December 31, 1998. The plutonium estimate assumes spent fuel contains on average 0.9% plutonium.

Thus, as summarized in Table 3, the United States has declared as excess only about one-third of the plutonium actually contained in intact weapons and stored weapon components. The United States is retaining 47 t of plutonium for weapons. The United States has not significantly reduced the size of its nuclear weapons stockpile since the unilateral nuclear weapon reduction initiative announced by Presidents Bush on September 27, 1991 (Figure 1); President Gorbachev made a similar announcement a week later, on October 5, 1991. By our estimates, the U.S. stockpile of nuclear weapons was about 10,400 at the end of FY 1998 (September 30, 1998) (Table 4). With START II fully implemented—the date for this has been extended until 2007—the United States plans to retain about the same number of intact nuclear warheads, plus an additional 5000 plutonium pits stored at Pantex to serve as a strategic reserve (Table 5).

Declarations of Excess Fissile Material by Russia

Excess Highly-Enriched Uranium. In 1992 Russia declared that it was willing to sell to the United States 500 t of HEU from weapons after blending it down (i.e., diluting it with natural or depleted uranium) in Russia into low-enriched uranium (LEU) for use as commercial power reactor fuel.[4] This was codified in a February 18, 1993, U.S.-Russian government-to-government agreement that specified that the HEU would have an average U-235 assay of 90 percent or greater. This, in effect, was the first and only declaration of excess HEU by Russia. Unlike the HEU declared excess by the United States, all of the Russian excess HEU is to be extracted from dismantled weapons, both Russian and Ukrainian. Russia has not declared how much HEU it and its predecessor, the Soviet Union, has produced. Outside experts have estimated the Soviet/Russian HEU inventory is on the order of 1100 to 1300 t.[5]

Excess Plutonium. Russia has also declared that 50 t of its plutonium is now in excess to its military needs. Russia has not revealed the sources of this plutonium—perhaps most or all of it will be from plutonium pits. Since Russia also has declined to declare its total plutonium inventory, Russia's declaration of excess plutonium leaves others unsure of how much plutonium Russia is retaining for weapon purposes. The Russian government has significantly larger inventories of both WGPu and separated reactor-grade plutonium (RGPu) than does the United States. We estimate that Russia has produced about 170 t of WGPu for weapons. There is an additional 30 t or so of mostly RGPu, recovered from processing spent fuel from VVER-440 power reactors and naval reactors and currently stored at Ozersk (formerly Chelyabinsk-65 or "Mayak").

Currently, Russia apparently plans to retain more than twice as much plutonium for weapons as the United States. Russia presumably is planning to retain at least as many intact nuclear warheads as the United States, i.e., on the order of 10,000 warheads under START II, and possibly considerably more—perhaps several thousand additional non-strategic warheads.

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[4] The sale of HEU from weapons was first proposed in 1991 by Thomas L. Neff, a physicist at MIT.

[5] Thomas B. Cochran, Robert S. Norris and Oleg A. Bukharin, Making the Russian Bomb (Boulder: Westview Press, 1995), p. 189.

On the other hand, if current trends continue, Russia will likely deploy fewer operational warheads than the United States.

Disposition of U.S. Excess Fissile Material

Excess Highly-Enriched Uranium. The United States has initiated programs to dispose of most of its excess HEU. Approximately 156 t of the 174.3 t of excess HEU is planned for disposition as commercial nuclear fuel. The United States has transferred to the United States Enrichment Corporation (USEC) 13.2 t (ultimately 14.2 t) of uranium in the form of enriched UF_6 for down blending into LEU, and signed a Memorandum of Agreement to transfer an additional 50 t of HEU (containing about 40 % U-235) over a five year period beginning in FY 1999. Currently this 50 t of HEU consists of 39.1 t of uranium metal and 10.9 t of uranium oxide (UO_2). Another 34.9 to 38 t of HEU, consisting primarily of high U-236 content uranium, will be blended down and used to fuel TVA power reactors over the next 10 to 15 years. In the future another 55 t of HEU will be blended down for use as commercial reactor fuel. The remaining 17.8 t of HEU in irradiated fuel will be disposed of as waste.

Excess Plutonium. The United States is pursuing two approaches to reducing the weapons-usability of the excess plutonium—irradiation of plutonium as mixed-oxide (MOX) fuel in currently operating nuclear power reactors, the so-called “MOX option,”[6] and immobilization of plutonium into stable forms containing fission products as a radiation barrier, the so-called “vitrification option.” In the former case the MOX fuel is to be burned in reactors and the spent MOX fuel is to be disposed of as a waste in a geologic repository. In the latter case, the plutonium oxide will be mixed with ceramic material and converted into a crystalline ceramic waste form, called a “puck” (each puck is about the size of a hockey puck). The pucks would then be placed in small cans which in turn would be incorporated into canisters containing vitrified high-level radioactive defense wastes. These so-called “can-in-a-canister” waste packages are to be sent to a geologic repository for permanent disposal. The repository at Yucca Mountain, presently under construction, faces considerable political and licensing hurdles. Even if it survives these hurdles, waste emplacement is not scheduled to begin until 2010 and further delays can be anticipated.

DOE has estimated the radiological risks associated with implementing the MOX and vitrification options in the United States.[7] Per tonne of plutonium processed, relative to the vitrification option, the MOX option is projected to produce a larger total committed dose to the workers, a larger total population exposure from routine emissions, and it carries a higher radiological risk associated with accidents.[8] Moreover, in the United States the MOX option is expected to take longer, and it is more expensive. The MOX option also encourages non-weapon states to rely on the more dangerous and inherently unsafeguardable closed fuel cycle for their civil

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[6] MOX fuel is a mixture of plutonium-oxide and uranium-oxide formed into ceramic pellets. The fuel pellets are inserted into rods which are bundled together to form fuel assemblies.

[7] U.S. Department of Energy, Office of Fissile Material Disposition, “Surplus Plutonium Disposition Draft Environmental Impact Statement,” DOE/EIS-0283-D, July 1998.

[8] Ibid., Volume 1, Part B, pp. 4-53 to 4-59.

power reactors. Despite these drawbacks the DOE is planning to dispose of 33 t of U.S. excess plutonium via the MOX option and 17 t via vitrification. Thirty-three tonnes is the maximum amount of plutonium DOE could dispose of as MOX. The other 17 t is in unsuitable forms, which is why it is being disposed of via the vitrification option.

DOE proposes to build a pit disassembly and conversion facility which will begin operating in FY 2005.[9] DOE also proposes to build a MOX fuel fabrication plant with a capacity to utilize 3.5 t of surplus plutonium per year, which is to operate for a period of 10 to 15 years beginning in FY 2007.[10] The vitrification plant will be designed to handle up to 5 t of plutonium metal per year. This annual throughput would consist of up to 1.7 t of surplus non-pit plutonium and up to 3.3 t of surplus plutonium derived from pits.[11] Design of the Immobilization and associated Processing Facility is scheduled to begin in FY 2000.[12]

The U.S. government's argument for implementing the dual-track approach in the United States is that the MOX option is the only option acceptable to Russia, and its implementation in the United States will enhance the probability of success of the Russian program. The United States and Russia completed a "Joint United States/Russian Plutonium Disposition Study" in September 1996. In this study Russia is on record as agreeing that, "The United States and Russia need not use the same [plutonium] disposition technology."[13] Thus, there is no compelling argument for allocating most of the U.S. excess plutonium to the MOX alternative. The U.S. and Russian disposition options are not so inextricably linked to require the maximum possible amount of U.S. excess plutonium to be converted into MOX. In my view both the United States and Russia should placed a much higher priority on implementing the vitrification option. And neither of these options is as important as verifiably dismantling nuclear weapon stockpiles and securing current inventories of weapon-usable nuclear materials.

Disposition of Russian Excess Fissile Material

Excess Highly-Enriched Uranium. On January 14, 1994, USEC, serving as the Executive Agent for the United States, entered into a contract with the Russian Federation to purchase over a 20 year period the LEU blended from 500 t of HEU extracted from Russian weapons. The contract was estimated in 1994 to be worth $11.9 billion (unadjusted 1993 dollars), based on an initial price of $780 per kilogram (kg) of 4.4%-enriched LEU, computed assuming $82.10 per SWU, and $28.50

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[9] DOE FY 1999 Congressional Budget Request, February 1998, Volume 1, p. 724. The preliminary total estimated cost of the pit disassembly and conversion plant is $346 million and the total project cost is $586 million.

[10] Ibid., p. 731. The preliminary total estimated cost of the MOX fabrication plant is $384 million, and the total project cost is $575 million.

[11] U.S. Department of Energy, Office of Fissile Material Disposition, "Surplus Plutonium Disposition Draft Environmental Impact Statement," DOE/EIS-0283-D, July 1998, Summary, p.S-18.

[12] DOE FY 1999 Congressional Budget Request, February 1998, Volume 1, p. 702.

[13] "Joint U.S./Russian Plutonium Disposition Study," September 1996, Executive Summary, p. ExSum-2.

per kg of uranium feed as UF_6.[14] In 1998 the contract was valued by USEC at $8 billion,[15] referring to the SWU component only.

Under the 1994 contract, 10 t of HEU (equivalent to about 310 t of LEU) were to be down blended and shipped to the United States during each of the first five years. Thirty tonnes of HEU (equivalent to about 930 t of LEU) were to be down blended and shipped during each of the subsequent 15 years. Subsequent LEU shipments have been at three different enrichments: 4.0%, 4.4% and 4.95%-enriched. According to USEC, as of August 1998, the following shipments had been made:

Year	LEU (t)	Derived from HEU (t)
1995	186	6
1996	371	12
1997	480	18
1998 (thru Aug)	294	8.8[16]
Total	1331	44.8

Additional shipments are in route which should bring the 1998 total through October to about 12 t HEU, or about 50 t HEU total to date. A total of 723 t of LEU, derived from 24 t of HEU, were ordered by USEC for delivery in 1998.

In December 1991—three weeks before the Soviet Union was dissolved and prior to the HEU agreement—in response to a petition by U.S. (and European) uranium mining interests, the U.S. Department of Commerce initiated an antidumping investigation to determine whether the Soviet Union was exporting uranium to the United States at less than fair market value. A preliminary ruling by the International Trade Commission went against the Soviet states. Under the trade law the "closest" free market was used to establish "fair value." Thus, even if the Soviet Union and the newly independent states had been selling uranium at a profit, they could have been (and were) found to be in violation of U.S. antidumping trade law. In October 1992, Russia and the other successor states agreed to restrict uranium imports into the United States, and in return the Department of Commerce suspended the antidumping investigations against them. Commerce also ruled that the "Suspension Agreement" between the United States and the newly independent states covered the natural uranium component of HEU.

Over the past six years the U.S. government has been engaged in a lengthy process of privatizing its uranium enrichment enterprise. USEC was established as a government owned corporation in October 1992 and it began operations in July 1993. Just over two months ago, on

[14] LEU is valued in terms of the amount of natural "uranium feed" that must be fed into a uranium enrichment plant and the amount of work or "services" performed by the enrichment plant, the latter being measured in "separative work units" (SWU). Assuming no losses and 0.3% tails assay, the ratio SWU/product = 6.0386 and the ratio feed/product = 9.975.

[15] See USEC web site: http://www.usec.com which directs one to: http://frontpage.USEC.inter.net/news_releases/8-24-98p.htm

[16] A total of 723 t of LEU, derived from 24 t of HEU, were ordered by USEC for delivery in 1998.

July 28, 1998, the privatization of USEC was completed with the transfer of the government's entire ownership in USEC to the private sector. USEC currently has approximately a 75 percent share of the North American uranium enrichment market and a 40 percent share of the world market. The company supplies enriched uranium to approximately 60 customers to use in 176 nuclear reactors located in 14 countries throughout the world.

As a consequence of all these competing interests, Russia has been unable to receive fair value for the LEU delivered to the United States. Under its contract with Russia, USEC pays for the SWU component of the LEU at the time of delivery. Now operating as a private business—and as a near monopoly, rather than an agent for national security—USEC has insisted that Russia accept a low value for the SWU component.

Under the 1992 Suspension Agreement, utility feed delivered in exchange for the uranium component of the LEU could not be resold in the United States in amounts in excess of those specified in the Suspension Agreement. This has prompted Russia to complained on numerous occasions that the suspension agreement and the privatization of USEC threaten the HEU deal. In response the U.S. government has pressured USEC into providing Russia with advanced payments against future deliveries of LEU. In mid-1994, $60 million was advanced, and in mid-1995 another $100 million was advanced against deliveries in 1996 and 1997. In December 1996, USEC transferred to the U.S. government the natural uranium equivalent of all the LEU purchases for 1995 and 1996, for which USEC paid Russia $160 million. At the same time USEC advanced Russia another $100 million against deliveries in 1998 and 1999.

On April 26, 1996, President Clinton signs into law the USEC Privatization Act which, among other things, directed USEC to return to the Russian Executive Agent the natural uranium component of shipments. The Act facilitated Russia's disposition of the natural uranium beginning in January 1997. Subsequent legislation gave Russia clear title to the feed component and permitted Russia to sell future deliveries of the uranium component. In 1997 Russia reached agreement in principle with Cameco, Cogema, and Nukem to sell the natural uranium component associated with LEU deliveries over the next ten years. To date there has been no public announcement indicating completion of natural uranium purchase arrangements between Russia and the Cameco/Cogema/Nukem consortium or any other buyers.

If one assumes the LEU derived from all 24 t of HEU contracted for 1998 delivery is shipped in 1998, then by the end of this year Russia will have at USEC an unsold inventory of approximately 11,000 t U as UF_6, worth about $300 million. As of mid-October the U.S. government was again seeking arrangements to rescue the troubled HEU deal by promising Russia aid to address falling uranium prices and reduced revenues due to lack of uranium sales.[17] Past advances were made by USCE when it was a government owned corporation. With USEC now privatized, any future advances will be have to come from the U.S. government.

According to Dr. Thomas Neff, at MIT, USEC could substantially increase its profits if the U.S-Russian uranium deal were terminated because it costs USEC’s less to produce SWUs than it

[17] “DOE Scrambles to Repair Russian Uranium Deal,” The Energy Daily, September 28, 1998, pp. 1-2.

does to buy SWUs from Russia, and because USEC's enrichment plants are currently operating at a lower efficiency than would be the case if USEC produced all the SWUs it was selling. For this reason, some USEC investors would prefer to see the uranium deal terminated, preferably by Russia over the natural uranium component so that USEC would appear blameless.

Plutonium. On September 2, 1998, Presidents Yeltsin and Clinton agreed to begin negotiations of a bilateral agreement that will lay out concrete steps for plutonium disposition and cooperation in this area. The U.S. already has detailed plans, so this agreement effectively applies only to Russia.

Russia faces several major difficulties in disposing of its plutonium. Russia has opposed use of the vitrification option, and Russia does not have a MOX fabrication plant with adequate capacity, nor funds to construct one. Various proposals for constructing a MOX fabrication plant in Russia have been floated by U.S. and Russian officials and European nuclear industry officials, but none nail down the financing. One proposal is for the U.S to build in Russia a plant for converting WGPu, currently in the form of weapon components (i.e., "pits"), into a different chemical and physical structure, so that the plutonium can be safeguarded without the risk of revealing sensitive weapon design data; and for Russia to finance the construction of a pilot MOX fabrication plant with money saved by borrowing against the money saved by displacing low-enriched uranium fuel. Russia, France and Germany have a joint proposal for constructing a pilot MOX plant with a capacity of 1.3 t of plutonium annually, sufficient capacity to supply fuel for four VVER-1000 plants operating on ~1/3 MOX cores (0.25 t Pu/reactor-y) and the BN-600 with a partial MOX core loading (0.3 t Pu/y). France and Germany are interested in constructing the Russian MOX pilot plant provided that someone else pays for it. To date neither U.S. commercial nor government entities has offered to finance the Russian plant and they appear unlikely to do so.

The 1.3 t Pu/y pilot MOX fabrication plant has a capacity of only 37 percent of the proposed U.S. MOX fabrication plant, and only 15 percent of the combined capacity of the U.S. MOX and vitrification facilities. Clearly, the Russian program is not keeping pace with the U.S. program even on paper. Moreover, the rate of conversion of plutonium using the proposed 1.3 t Pu/y pilot MOX fabrication plant is too slow in light of the fact that Russia is currently, and plans to continue, separating plutonium from VVER-440 power reactors and three plutonium production reactors. In recent years about 2 t of plutonium were being separated annually from VVER-440 spent fuel processed at Chelyabinsk-65, and about 1.4 t of plutonium is being recovered annually by processing spent fuel from the three remaining plutonium production reactors—two reactors at Tomsk-7 and one at Krasnoyarsk-26. Consequently, even if the proposed pilot MOX fabrication plant were to be constructed in Russia, its 1.3 t Pu/y capacity is less than 40 percent of the rate at which Russia continues to separate plutonium. Russia plans to stop processing production reactor fuel in the year 2000, when the reactors are scheduled to shift over to a different fuel type. Even so, under current plans Russia would still be separating plutonium as fast as it is converted to MOX.

The current DOE policy is not to construct the U.S. MOX fabrication plant unless there is "significant progress with Russia on plans for plutonium disposition" by the end-FY 2000 [September 30, 2000].[18] Since it is highly probable that there will be little progress on plutonium

[18] Statement of Howard Cantor, Acting Director, Office of Fissile Material Disposition, at the Council on Foreign Relations

disposition in Russia over the next several years, there may be little or no U.S. plutonium converted into MOX for years to come.

Probably underlying much of the negative Russian reaction to the vitrification disposal option is a valuation of plutonium derived from production costs to the State and from the substantial health and environmental consequences of its production. "We got it with blood and sweat, and that would be incorrect to just push it away," Minister of Atomic Energy Yegeny Adamov stated at the U.S.-Russian talks held earlier last month in Moscow.[19] The Minister may not appreciate that no weight should be given to sunk costs in decisions related to future investments.

The Continued Commercial Use of Plutonium Is a Threat to Global Security

British Nuclear Fuel, Limited (BNFL) in the United Kingdom and Cogema in France are reprocessing spent nuclear fuel to recover and recycle the plutonium in commercial power reactors. Prior to the plant being shut down on March 11, 1997, following a fire and explosion accident, Japan had processed 940 t of spent fuel at its Tokai reprocessing plant. Russia recovers plutonium from VVER-440 power reactor and naval reactor spent fuel at Chelyabinsk-65, and would like to develop an industrial-size MOX fuel fabrication plant to close the fuel cycle in Russia. India reprocesses spent fuel, and Pakistan is developing a reprocessing capability for military and ostensibly for civil and military purposes. All of these programs are a threat to global security. Commercial plutonium use will make deep reductions in global nuclear weapon arsenals impossible; it cannot be adequately safeguarded; and it provides a breakout capability for obtaining nuclear weapons. Moreover, commercial plutonium use is uneconomical and therefore unnecessary.

The overriding argument for not reprocessing and recycling plutonium, even if it were economical to do so, derives from the fact that separated plutonium is usable in nuclear weapons and it requires very little plutonium to make a weapon. A pure fission nuclear weapon with a yield of one kiloton can be made with as little as one to three kilograms of weapon-grade plutonium, depending on the sophistication of the implosion technique employed. A weapon of the same yield, but made with reactor-grade plutonium would require about 20-30 percent more plutonium. Modern thermonuclear primaries with yields of several kilotons are made with about three kilograms of plutonium.

Despite these facts European and Asian governments have permitted an enormous surplus of plutonium separated from civil nuclear power reactor spent fuel to built up in Europe and Asia. France, the United Kingdom, Japan and Russia continue to separate plutonium at a far greater rate than it is being burned in existing reactors even though 28 reactors are loaded with MOX fuel in Europe (15 in France, 8 in Germany, 3 in Switzerland and 2 in Belgium).[20] France and the

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"The Management and Disposition of Excess Nuclear Weapons Material," March 9, 1998.

[19] "Russian-American Talks on War Plutonium to be Held in Sept," Veronika Romanenkova, ITAR-TASS News Agency, September 4, 1998.

[20] L.F. Durret, "Management of Waste and Spent Fuel," The Atlantic Council of the United States Global Seminar on the Future of Nuclear Power, Cannes, France, May 10-12, 1998.

United Kingdom are separating about 20 t of plutonium per year, but only 9 t were recycled into fuel in 1997.[21] The U.K stockpile of separated civil plutonium (i.e., not fabricated into fuel or in use in reactors), including that owned by Japanese and other foreign utilities, now stands at 50 t and is projected to grow to 100 t by 2010.[22] As of the end of 1997, Japan had accumulated 24 t of separated plutonium, of which 5 t was stored in Japan and 19 t was stored in France and the United Kingdom.[23] The global inventory of separated civil plutonium is now an estimated 170 t—some 3.6 times the 47 t of plutonium reserved by the United States for weapons and comparable to stocks of plutonium reserved for weapons by all nuclear powers.

The accumulation of large stockpiles of separated plutonium and weapon-usable expertise in nominally civil programs will act as a barrier to deep reductions and eventual elimination of nuclear weapons held by declared and undeclared weapon states. One need only ask how far China, for example, might be willing to go in accepting limits on, or reductions in its nuclear weapons stockpile if Japan is poised to accumulate an even larger inventory of weapons-usable fissile materials in pursuit of a civil plutonium program with no clear commercial rationale. Similarly, Russia's continued operation of three reprocessing plants and Russia’s committed to the deployment of BN-800 type breeder reactor and a closed fuel cycle fuel, could abort U.S. political support for continuing toward very deep reductions and ultimate abolition of nuclear weapons stockpiles. The lack of such a commitment by the United States and other nuclear weapons states, could, in turn, lead to continued erosion of the nonproliferation regime. Hence, there is a need to forthrightly address the mistaken legitimacy afforded civil plutonium programs under the current system of international controls. In any case, nations having civil nuclear energy programs with closed fuel cycles can make an important contribution to the disarmament process by deferring further separation of plutonium until the global inventories of plutonium are substantially reduced.

Given the small quantity of fissile material need to make a nuclear weapon, highly accurate material accounting and control measures are essential to determine whether a theft has taken place, and to provide timely warning to prevent the material from being used for illicit purposes. It is well established—from experience at existing civil and military chemical separation (reprocessing) plants, naval fuel facilities, and mixed-oxide fuel facilities—that it is extremely difficult (we would argue impossible) to provide in practice adequate material control and accounting, at bulk handling facilities where large amounts of nuclear weapons-usable material are processed in the form of liquids, gases and/or powders. At present there is no way to determine through inventory procedures whether weapon-quantities of plutonium are being diverted from these military and civil bulk handling facilities.

Not only is there no adequate means of safeguarding large bulk handling facilities to prevent weapon-usable plutonium from being stolen, but also reprocessing of spent fuel and the recycling of plutonium[24] into fresh fuel for reactors permit non-nuclear weapons states to justify the acquisition

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[21] Frank von Hippel, “How to Simplify the Plutonium Problem, Nature, July 30, 1998, p. 415.

[22] Ibid.

[23] Nuke Info Tokyo, July/Aug. 1998, p. 5.

[24] Or any other weapons material, such as highly enriched uranium or uranium-233.

and stockpiling of nuclear weapons-usable material—ostensibly for peaceful purposes. At the same time, without violating any international safeguards agreements, these countries can design and fabricate non-nuclear weapon components. By moving to a point of being within hours of having nuclear weapons—perhaps needing only to introduce the fissile material into the weapons—a nascent weapons state would have all of its options open. Under these conditions, international safeguards agreements can serve as a cover by concealing the signs of critical change until it is too late for diplomacy to reverse a decision to "go nuclear." India recovered the plutonium for its first nuclear device in a reprocessing plant that was ostensibly developed as part of its "peaceful" breeder program.

Currently, Iraq, Iran, North Korea and probably Libya are pursuing nuclear weapons. Iraq and North Korea have been caught violating their Nuclear Nonproliferation Treaty (NPT) and IAEA obligations. According to a recent press report, U.N. arms inspectors reported twice to the United States, in 1996 and 1997, that they had credible intelligence indicating that Iraq built and has maintained three or four implosion devices that lack only the cores of enriched uranium to make 2 kiloton nuclear weapons.[25] The North Korean "Agreed Framework" to limit this state's nuclear program is stalled, for reasons which include recent satellite imagery of construction activities which may be associated with clandestine nuclear weapons activity, and the test firing of a three-stage missile (and partially successful satellite launch) which passed over a portion of Japan. Less than one year into what many thought would be a long-term global moratorium on nuclear testing, India and then Pakistan successfully demonstrated—at a minimum—fission weapon technological capability, and India claims to have tested a hybrid two-stage thermonuclear device. Terrorists attacks represent a growing threat, both in the frequency of attacks and kinds of explosives devices that are being used. Clearly, this is not the time to be promoting technologies that require the stockpiling of nuclear weapon-usable materials, or promoting the commercial use of inherently unsafeguardable facilities.

Economics of Plutonium Use as a Reactor Fuel

It would be another matter if there were a strong economic incentive to reprocess and recycle plutonium commercially; but this is not the case. The U.S. National Academy of Sciences (NAS) prepared a comprehensive comparison of the relative cost of fresh low-enriched uranium (LEU) and MOX fuel.[26] The NAS took as its baseline fuel characteristics:

	LEU fuel	MOX fuel
Fuel enrichment	4.4% U-235	4.8% WGPu; 95.2% DU (0.25% U-235)
Fuel burnup	40,000 MWd/tHM	40,000 MWd/tHM
capacity factor	75 percent	75 percent

[25] Barton Gellman, "Iraqi Work Toward A-Bomb Reported, The Washington Post, September 30, 1998, p. A1.

[26] National Academy of Sciences, Committee on International Security and Arms Control, " Management and Disposition of Excess Weapons Plutonium" (Washington, D.C.: National Academy Press, 1995), pp. 280-329.

typical of fuel for pressurized water reactors, including fuel for the Russian VVER-1000 reactor. The NAS estimate for the cost of LEU fuel was $1400 ± 200 per kilogram of heavy metal (kgHM),[27] and for MOX fuel was $2100 ± 300 per kgHM,[28] or about 50 percent greater. Thus it is uneconomical to use plutonium as a fuel for commercial power reactors, even if the plutonium is provided at no cost, as is the case when one attempting to dispose of excess plutonium from weapons.

The economics of a closed fuel cycle relative to the open cycle is even worse than the case outlined above where the plutonium is already separated. To obtain the plutonium needed to fabricate one tonne of MOX fuel, one must reprocess some five to seven tonnes of spent LEU fuel, at a cost of more than $1000 per kgHM in the spent fuel. While some credit is received for the extra unused uranium recovered, even so, the life cycle cost of fuel under the closed cycle is about twice the life cycle cost of fuel when operating an open fuel cycle.

Many nuclear engineers who do not understand or appreciate economics, argue that one must use the plutonium to get the maximum energy value out of the uranium fuel. If this logic had merit we should be collecting all the energy from sunlight and storing it in batteries rather than letting it go to waste. We don’t do this because it is uneconomical to do so. As with solar energy, one can always introduce plutonium recycling and fast breeder reactors, and thus achieve a practically inexhaustible supply of nuclear energy, but it makes no sense whatsoever to do this before the closed fuel cycle is economically competitive with the open fuel cycle.

Another bogus argument is that plutonium recycling is needed for waste management purposes. Actually, the closed cycle results in larger volumes of low-level and transuranic wastes and smaller volumes of uranium mining and milling wastes and high level waste. Moreover, the high-level mixed waste from reprocessing represents a dangerous and difficult-to-manage waste form in comparison to encapsulating spent fuel. In terms of health effects from routine operations and the risks to future generations, it is difficult to conclude that either cycle is preferred.

Summary and Conclusion

The United States has declared that 52.5 t of plutonium and 173.4 t of HEU are in excess of military needs, and Russia has declared that up to 50 t of plutonium and 500 t of HEU are in excess. Only 22.7 t of the U.S. excess plutonium was in pit form when the declarations were made. Similarly, only 83.3 t of the excess HEU was in metal form and none of this was enriched to 90% U-235, or greater. The United States is retaining sufficient military stocks of plutonium and HEU to retain some 10,000 nuclear weapons under START II and an additional 5,000 pits and several thousand intact secondary components.

[27] Ibid., p. 290.

[28] Ibid., p. 294. Without property tax and insurance the cost was estimated to be $1900 ± 300 per kgHM.

Even though its declaration of excess plutonium (in pit form) and HEU are greater than those of the United States, Russia is currently planning to retain more plutonium and HEU (and weapons) than the United States. All in all these declarations do not have a significant arms control impact.

To use the "swords into ploughshares" analogy, both Russia and the United States are retaining vast quantities of "steel" to make new swords should the need arise. The United States and Russia are each hiding the relative magnitude of their respective HEU reductions by refusing to reveal the size of the HEU inventories each is retaining for military purposes.

The U.S. program for blending down its relatively small excess HEU stockpile into reactor fuel is functioning smoothly, albeit slowly. The success of the Russian HEU disposition program is being threatened by Russia inability to receive equitable and prompt value for the LEU delivered to the United States. This is a consequence of the restrictions placed on the sale of the natural uranium component in the United States and the low price for enrichment services offered by USEC.

The U.S. program for disposing of its excess plutonium is making slow progress, but could stall if there is not significant progress on the Russian side. The Russian plutonium disposition program is stalled for lack of funding, and in any case cannot keep pace with the rate of separation of new plutonium in Russia.

The current surplus of separated plutonium in the civil plutonium use programs in Europe and Asia represents a threat to the national security of the United States and other nations, and this surplus is an impediment to the abolition of nuclear weapons. It is ironic that the United Kingdom, France, and Japan are compounding security risks by commercially separating plutonium from spent fuel while the United States and Russia seek to put excess plutonium back into spent fuel to reduce the national security threat to all nations. Meanwhile, the more important tasks involved in the business of getting on with nuclear warhead reductions—such as verifying nuclear warhead elimination and nuclear warhead and fissile material stockpile inventories—remain stalled while additional nations announce their accession to the nuclear club and others openly flout the mandates of the international community.