

**Progress in U.S./Russian Transparency
and
Fissile Material Disposition**

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Preface

This paper is excerpted from Thomas B. Cochran, Robert S. Norris, and Christopher E. Paine, "Progress in Nuclear Weapon Elimination," presented at the 25th Workshop on Nuclear Forces, *Problems in Achieving a Nuclear-Free World*, London, 25-27 October 1996.

Data Exchange, Transparency and Verification Measures

On 10 May 1995 Presidents Clinton and Yeltsin issued a “Joint Statement on the Transparency and Irreversibility of the Process of Reducing Nuclear Weapons.” This joint statement represents the fullest and most recent description of the intentions of the two countries with regard to warhead dismantlement and transparency. Among the key provisions of this joint statement, the U.S. and Russia agreed to establish:

- An exchange on a regular basis of detailed information on aggregate stockpiles of nuclear warheads, on stocks of fissile materials and on their safety and security;
- A cooperative arrangement for reciprocal monitoring at storage facilities of fissile materials removed from nuclear warheads and declared to be excess to national security requirements to help confirm the irreversibility of the process of reducing nuclear weapons, recognizing that progress in this area is linked to progress in implementing the joint U.S.-Russian program for the fissile material storage facility at Mayak; and
- Other cooperative measures, as necessary to enhance confidence in the reciprocal declarations on fissile material stockpiles.

With respect to transparency, the agreement also states that:

The United States of America and the Russian Federation will also examine and seek to define further measures to increase the transparency and irreversibility of the process of reducing nuclear weapons, including intergovernmental arrangements to extend cooperation to further phases of the process of eliminating nuclear weapons declared excess to national security requirements as a result of nuclear arms reduction.

The United States of America and the Russian Federation will seek to conclude in the shortest possible time an agreement for cooperation between their governments enabling the exchange of information as necessary to implement the arrangements called for above, by providing for the protection of that information. No information will be exchanged until the respective arrangements enter into force.

Unfortunately, there has been no progress between the United States and Russia on implementation of the agreed upon data exchange, or any warhead dismantlement and fissile material storage transparency and verification measures, since October 1995, when without explanation Russia cut off bilateral talks directed toward concluding an Agreement for Cooperation, the legal instrument that would permit the data exchange and transparency measures to go forward. Russian hard-liners among President Yeltsin’s inner circle were apparently responsible for this turn of events.

Russia's refusal to move forward with an Agreement for Cooperation has brought to a halt virtually all reciprocal transparency initiatives related to nuclear warhead dismantlement and warhead component storage, including (a) a U.S. proposal for mutual inspections of warhead storage and dismantlement sites to verify the rate at which nuclear warheads are being dismantled, the number that await dismantlement, and the number that have been dismantled already, and (b) the demonstration of techniques for verifying the presence of pits and other nuclear weapon components in sealed storage containers.

Storage and Disposition of Nuclear Weapon-Usable Fissile Materials

United States

Plutonium. Table 1 summarizes the amount of plutonium acquired and utilized by the DOE (and its predecessor agencies). The existing inventory of 99.5 metric tons (t), by our estimates consists of 85.1 t of weapon-grade plutonium (WGPu is < 7% Pu-240), 13.2 t of fuel-grade plutonium (FGPu is from 7% to < 19% Pu-240), and 1.2 t of reactor-grade plutonium (RGPu is \geq 19% or greater Pu-240).

The location of the existing inventory is given in Table 2, as best we can discern from recent DOE waste management reports. The U.S. government has declared that 38.2 t of WGPu are in excess of military needs and are being permanently withdrawn from the United States nuclear weapons stockpile. However, 16.9 t of this "excess" material – much of it scrap and residues – are not in pit form and are stored at various sites that are no longer part of the nuclear weapons program. The U.S. government also has declared that none of the 14.4 t of FGPu and RGPu will be used for nuclear weapons (Table 3).

The FGPu and RGPu were used primarily for peaceful purposes— including, for example, some 5.2 t of FGPu in unprocessed irradiated N-Reactor fuel at Hanford, about 0.5 t of FGPu in fresh FFTF fuel assemblies at Hanford, and 3.8 t of fuel elements at the Zero Power Plutonium Reactor (ZPPR) complex, a critical assembly facility, at Argonne National Laboratory-West (ANL-West at the Idaho National Engineering Laboratory (INEL)). Thus, the total plutonium of all types declared excess is 52.6 t, leaving 46.9 t of WGPu for weapons, of which 44.8 t is currently in weapons and intact pits stored at Pantex.

By the end of FY 1999 DOE will have recovered some 12,000 pits since FY 1990. The vast majority of these pits will be stored at Pantex--the exception being a few tens of pits sent to the national labs for analysis and reassembly, and any pits dismantled as part of DOE's long-term plutonium disposition program. Currently Pantex has the capacity to store 20,000 pits, but DOE has agreed to store no more than 12,000 pending completion of a site-wide Environmental Impact Statement (EIS). We estimate the mass of the 12,000 pits will total about 36 t of WGPu. Since only 21.3 t of the WGPu in pits at Pantex and in yet to be dismantled warheads has been declared excess, we estimate that

the United States currently is planning to retain as a strategic reserve, some 5,000 intact pits containing approximately 15 t of WGPu.

Of the 52.5 t of excess plutonium, the United States has placed approximately 2 t of plutonium under International Atomic Energy Agency (IAEA) safeguards. This includes approximately 1 t of fuel-grade PuO₂ at the Plutonium Finishing Plant Vault at Hanford, and approximately 1 t of weapon-grade “foundry oxide” and Pu/EU oxide in Building 371 at Rocky Flats.¹

The United States since 1993 has been moving forward with a process for determining how to dispose of its excess plutonium. Key decision documents are identified in Appendix A. To establish a framework for selecting plutonium disposition options which would achieve a high degree of proliferation resistance, the National Academy of Sciences (NAS) endorsed as one of its recommendations the “spent fuel standard.” Adopting this recommendation, the DOE defines this criterion as,

A concept to make plutonium as unattractive and inaccessible for retrieval and weapons use as the residual plutonium in the spent fuel from commercial reactors.

The DOE completed a screening process in March 1995, and a Draft Programmatic Environmental Impact Statement in February 1996, and has narrowed the surviving plutonium disposition options to three categories:

- (1) Plutonium burning in a once-through reactor cycle as mixed oxide (MOX) fuel followed by disposal in a repository;
- (2) Immobilization in an acceptable matrix to create an environmentally benign form for disposal in a repository;
- (3) Disposal in deep boreholes (with or without prior fixation).

There are several sub-options under each of the categories that are still in contention:

- (1) MOX Options:
 - a. Using existing LWRs
 - b. Using a partially completed LWR
 - c. Evolutionary LWR
 - d. Using Canadian CANDU reactors
- (2) Immobilization Options:
 - a. Vitrification:

¹ The fuel-grade PuO₂ at Hanford comprised 1100 items and is limited to <17% Pu-240 to reduce radiation exposure. The weapon-grade PuO₂ at Rocky Flats comprises approximately 700 items.

- i. Greenfield glass
 - ii. Adjunct Melter
 - iii. Can-in-canister
 - b. Ceramic
 - i. Greenfield ceramic
 - ii. Can-in-canister
 - c. Electrometallurgical Treatment
- (3) Deep Borehole Options:
- a. Direct Emplacement
 - b. Immobilized Emplacement
- (4) Combinations of two or more of the above alternatives.

Given that there is no constituency for disposal of surplus plutonium in deep boreholes (the third category), this method of disposal is unlikely to be selected. Nevertheless, in deference to earlier recommendations by the NAS, two deep borehole disposal options are still under consideration by DOE.

The surplus plutonium is currently in a wide variety of chemical and physical forms. Some plutonium is in metal, oxide or solutions, some already in spent fuel, and some is in scrap and residues with plutonium concentrations less than 50 percent. Conversion of plutonium from spent fuel or residues to MOX is not an attractive alternative from the standpoint of the purity of the feed material. Thus, DOE appears to be leaning toward a “hybrid option,” a combination of one of the MOX options and one of the immobilization options. In Table 4, we have broken down the surplus plutonium by category. As seen from the table, approximately 37 t of plutonium appears suitable for conversion to MOX from the standpoint of the purity of the feed material, about 7 t is likely to be immobilized, and the remaining 8 t is already in the form of reactor fuel.²

The United States currently has no operating MOX fabricating capability. Thus implementation of the MOX option in the United States is several years away in any case.

Highly-Enriched Uranium. DOE has announced that it produced through 1992 for all purposes, 994 t of HEU, defined as uranium having an enrichment above 20% U-235.³ In Table 5 we present our accounting of DOE's HEU inventory. The uncertainties associated with some of our HEU inventory estimates are large. We look forward to

² According to DOE, approximately 32.5 t of the surplus plutonium comprises “plutonium metals and oxides from weapon dismantlements and other high purity weapons-grade oxides and metal,” and 17.5 t is “lower-purity or non-weapons grade metals and oxides, and various plutonium materials including fresh fuel forms, halides, and compounds;” DOE, Office of Fissile Material Disposition, “Technical Summary Report for Surplus Weapons-Usable Plutonium Disposition,” DOE/MD-0003, July 17, 1996, p. 2-3.

³ DOE, Openness Press Conference Fact Sheets, June 27, 1994; 483 t was produced at the Oak Ridge K-25 site and 511 at the Portsmouth Gaseous Diffusion Plant in Portsmouth, Ohio.

improved estimates, as DOE is in the process of reconciling U.S. HEU production, usage and existing inventories in order to publicly release additional HEU data.

We have assumed that in recent years the U.S. had about 500 t of oralloy (~93.5% U-235) in weapons or assigned for weapon use.⁴ We believe this estimate is accurate to within ± 10 t. In addition, some thermonuclear secondaries contain uranium that has been enriched to something between 20% and 90% U-235, as evidenced by the fact that the DOE in 1995 transferred to the U.S. Enrichment Corporation (USEC) 50 t of weapons HEU, of which 5 t was 70%-enriched and 45 t of 37.5%-enriched.⁵ Although technically this is HEU because it is enriched to $\geq 20\%$ U-235, we will refer to it as medium-enriched uranium (MEU), to distinguish it from oralloy (~93.5% U-235). The amount of MEU produced for weapons is not known by us. We have assumed it was on the order of 100 t of oralloy equivalent, and further assumed that 10 percent was at 70%-enriched and 90 percent was 37.5%-enriched, similar to the material turned over to USEC. Thus, we assume that there were about 23 t of 70%-enriched uranium and 206 t of 37.5%-enriched uranium.

On 27 June 1994, DOE also released the HEU inventories at various DOE sites (totaling 258.8 t HEU), but continued to classify the HEU in weapons, weapon components stored at Pantex, and naval fuel (Table 5). These estimates serve as a basis for NRDC's estimate of the HEU inventories as of October 1996, also shown in Table 5.⁶

On 6 February 1996, DOE announced the locations of 174.3 t of HEU that the United States has declared is in excess of military requirements—about 33 t enriched to over 92% U-235, and about 142 t enriched to between 20% and 92% U-235—of which 104 t was in a form that could be blended down for use as commercial reactor LEU fuel (Table 5). Thus, only about one-half of the HEU that has been declared excess was ever in weapons or meant for weapons. The remainder includes 26.2 t of HEU at INEL and ANL-West, and 22 t, containing about 50% U-235 and about 25-35% U-236, at the Savannah River Site. The latter started as fresh 97.3%-enriched naval reactor fuel, was subsequently recovered from spent naval fuel, then used to make fresh Savannah River production reactor fuel, and then recovered again, which accounts for the high concentration of U-236. Also declared excess was some very highly-enriched uranium that was intended to be naval fuel but which did not meet Navy specifications. The 84.9 t of excess HEU at the Y-12 plant included 10 t of HEU oxide in Vault 16 already under IAEA safeguards.

In the last five columns of Table 5, we give our estimate of the planned future use of the U.S. government HEU. We have assumed that about 330 t of HEU will be retained in and for weapons, including about 275 t in approximately 10,000 warheads that will remain

⁴ Thomas B. Cochran, William M. Arkin, Robert S. Norris and Milton M. Hoenig, *Nuclear Weapons Databook*, Volume II: U.S. *Nuclear Warhead Production* (Cambridge, MA: Ballinger Publ. Co., 1987), p. 191.

⁵ William Broad, "Quietly, U.S. Converts Uranium into Fuel for Civilian Reactors," *New York Times*, 19 June 1995, p. A10.

⁶ See also, *Nuclear Weapons Databook*, Volume II: U.S. *Nuclear Warhead Production*, Appendix D.

intact, and a strategic reserve which we estimate at 60 t—sufficient for an additional 2,000 warheads. “Currently, secondaries shipped from Pantex to the Y-12 Plant are scheduled for interim storage and subsequently disassembly, except those secondaries designated as part of the strategic reserve that are placed directly into storage.”⁷

We are told that the Navy has refused to permit any or alloy metal from being included in the excess HEU category, in order to retain it for future use as naval reactor fuel. We estimate the Navy is reserving about 320 t of or alloy to future use. While this estimate is highly uncertain, we have heard that the amount currently being reserved for navy use represents a 100+ year reserve.

Of the 174.3 t of HEU already declared surplus, DOE believes about 113 t can be used for commercial fuel, including 63 t already turned over to USEC and 10 t under IAEA safeguards at the Y-12 plant in Oak Ridge. DOE believes the other approximately 62 t is not likely to be commercially available. About 50 t of MEU from weapons and 13 t of HEU out-of-spec Navy fuel—both part of the excess—has already been turned over to the U.S. Enrichment Corporation (USEC) for blending to make low-enriched uranium (LEU) fuel for future use in commercial power reactors. From Table 5, which includes additional HEU that has not yet been declared excess, we estimate that perhaps as much as 145 t of HEU can be made available for commercial fuel.

Russia

Plutonium. Soviet/Russian nuclear weapon plutonium production, which began in 1948, probably amounts to some 150-170 t, of which an estimated 115-130 t was actually fabricated into weapon components (the rest is assumed to be in production scrap, solutions, residues).⁸ In addition, Russia has about 30 t of separated reactor-grade plutonium in storage at Chelyabinsk-65 that was recovered primarily from VVER-440 and naval reactor spent fuel.⁹

Russia has not made any public declaration regarding how much weapons plutonium was produced, the amount in the current inventory, the amount now believed to be excess to Russia’s national security needs, the number of plutonium pits currently

⁷ DOE, Defense Nuclear Facilities Safety Board, “Status of Highly Enriched Uranium Processing Capability at Building 9212 Oak Ridge Y-12 Plant,” DNFSB/TECH-9, December 8, 1995, p. 5.

⁸ The upper limit of Soviet plutonium production is from Cochran, et al., *Making the Russian Bomb: From Stalin to Yeltsin*, Appendix C. The lower limit is from Anatoli S. Diakov, “Disposition of Separated Plutonium: an Overview of the Russian Program,” paper presented at the Fifth International Conference on Radioactive Waste Management and Environmental Remediation, September 3-8, 1995, Berlin, Germany. The fraction of pipeline materials, i.e., solutions, scrap, and residues, in the Russian weapon program is assumed to be comparable to that in the U.S. weapon program.

⁹ The U.S. General Accounting Office (GAO) also estimates that “The Soviet Union produced up to 1,200 metric tons of HEU and 200 metric tons of plutonium.” U.S. General Accounting Office (GAO), “Nuclear Nonproliferation: Status of U.S. Efforts to Improve Nuclear Material Controls in Newly Independent States,” GAO/NSIAD/RCED-96-89, March 1996, p. 17. The authors of this report have stated privately that this is a U.S. DOE estimate based on Russian sources.

in storage and the locations of these sites, the total number of pits disassembled, or the rates of warhead and pit disassembly. The U.S. government believes most of the pits from disassembled Russian warheads are stored intact.

In July 1992, Minatom put forward a conceptual program of development of nuclear power in Russia that called for the construction of up to four BN-800 liquid metal fast breeder reactors—completion of up to three reactors at the South-Ural site at Chelyabinsk-65 and construction of an additional reactor at Beloyarsky.¹⁰ Senior Minatom officials over the past several years have expressed a strong preference for using excess military plutonium as MOX fuel, preferably in the yet to be built BN-800s. However, within the last year or two they have come to recognize that funding is unavailable to support an ambitious fast reactor construction program. Breeders are now viewed by Minatom as potentially needed in 20-30 years.

However, senior Minatom officials still favor the MOX option and oppose direct geologic disposal following immobilization of the plutonium in glass. They now recognize that the only viable MOX option is to use existing reactors, namely VVER-1000 reactors and the single BN-600 at Beloyarsky. There are seven operating VVER-1000 in Russia and an additional 10 in Ukraine. VVER-440 reactors are not an option in Minatom's view. If modified to accept a full core load of MOX, VVER-1000s can burn about one tonne of plutonium per reactor-year. For safety reasons Minatom believes the BN-600 is limited to one-fourth core loading.

Requested by Presidents Yeltsin and Clinton at their 14 January 1994 summit meeting, a Joint United States/Russian Plutonium Disposition Study dated September 1996 was released by the two governments just prior to the G-7 Experts Meeting in Paris on 28-30 October 1996. This study examined plutonium storage, pit conversion and stabilization of unstable forms, and the feasibility of various plutonium disposition options, including MOX in light water reactors, HTGR, Candu, and fast reactors, as well as vitrification and geologic disposal and accelerator based conversion. The United States and Russia have agreed to continue to cooperate in the development, testing, demonstration and analysis of technologies for plutonium pit conversion and plutonium disposition, including validation of computer codes for modeling the safety of MOX use in VVER-1000 and Candu reactors and the single existing BN-600 reactor operating as a "burner," fabrication of VVER and Candu MOX fuel, immobilization of plutonium in different glass forms, and modeling geological disposal. The United States will probably devote a few million dollars from the Nunn-Lugar account to these activities.

The U.S. President's Committee of Advisors on Science and Technology (PCAST) and the Russian Academy of Sciences (RAS) are sponsoring a parallel joint U.S.-Russian study addressing the plutonium disposition issue. This independent "non-government" scientific commission has issued an "Interim Report of the US-Russian

¹⁰ The Concept of Development of Nuclear Power in the Russian Federation, 14 July 1992, The Council (Kollegia) of the Minatom RF.

Independent Scientific Commission on Disposition of Excess weapons Plutonium,” 16 September 1996. This commission plans to issue a final report in early 1997. The two governments, however, are under no obligation to follow their recommendations.

An important conclusion of the Joint United States/Russian Plutonium Disposition Study is that “disposition of excess weapons plutonium should proceed in parallel, with the goal of reductions to equal levels of military plutonium stockpiles.”¹¹ This was also one of the recommendations of the US-Russian Independent Scientific Commission. Since the United States is currently planning to retain about 50 t of plutonium for weapons and dispose of about 50 t, and since Russia has about 200 t, this joint statement implies that Russia should dispose of its plutonium at a rate at least three times that of the United States. It is unlikely that this goal can be met if Russia relies primarily on the MOX option. Russia, like the United States, has no large-scale operating MOX fabrication plant and lacks funds to construct a new one. Even if a new MOX fabrication facility is financed by the West, after it becomes operational, for Russia to reduce its separated plutonium inventory from 200 t to 50 t would require the equivalent of 270 years of operations of existing VVER-1000s, each operating with full cores of MOX fuel, or about 17 years of operation of 16 VVER-1000 reactors—all seven VVER-1000 reactors in Russia, and the 11 operating VVER-1000 reactors in the Ukraine.¹²

Both the United States and Russia have agreed to place excess plutonium and HEU under IAEA safeguards, and DOE and Minatom are meeting jointly with the IAEA staff to discuss implementation of this offer. The United States has already placed token amounts of excess plutonium and HEU under IAEA safeguards. Minatom has not done so. Neither the United States nor Russia have declared how much plutonium or HEU will ultimately be placed under IAEA safeguards.

Highly-Enriched Uranium. As with plutonium, Russia has not declared how much HEU it has produced, how much it is reserving for weapons use, or how much is in excess of military needs. While the total production of Soviet/Russian HEU for weapons is not accurately known, the DOE believes it is on the order of 1200 t.¹³ Assuming Russia retains about 10,000-11,000 warheads in 2004, these will contain about 300-330 t of HEU. In 1993 Russia agreed to sell to the United States 500 t of HEU (90 percent U-235 equivalent) from weapons. This leaves an estimated 400 t of HEU that will not be in weapons in 2004, and has not been offered for sale.

Although in 1993 Russia agreed to sell 500 t of HEU to the United States, the contract signed in January 1994, called for the sale of *up to* 500 t of HEU equivalent—at a rate of up to 10 t per year for the first five years, and 30 t per year for the next 15 years.

¹¹ *Joint United States/Russian Plutonium Disposition Study*, September 1996, p. Sum-32.

¹² *Ibid.*, p. WR-11.

¹³ See footnote 9 above.

Thus far, the U.S. Enrichment Corporation (USEC), the executive agent for the United States government in managing the contract, has taken delivery in 1995 of LEU equivalent to 6 t of HEU, and contracted for an additional 12 t of HEU equivalent in 1996 (more than half of which has been delivered to date).

In January 1996, Russia offered to sell 18 t of HEU as LEU in 1997, rather than the previously agreed 12 t. USEC, with DOE approval, initially refused to accept the larger amount. Following pressure from Capitol Hill, The Department of Energy subsequently pressured USEC to accept the full 18 t, but USEC had not yet negotiated a price as of mid-September 1996. Minatom would like to sell 24 t of HEU equivalent in 1998.

The United States is in the process of privatizing its uranium enrichment enterprise. The relevant legislation on privatization of USEC was passed in April 1996. Once the privatization is completed, depending on market conditions, USEC may continue to have a strong financial incentive to offer Minatom an unacceptably low price, or stall future deliveries by other means, for some of the HEU Minatom offers for sale. How this plays out, and the extent to which the HEU purchase agreement is affected, remains to be seen. The U.S. government always has the option of removing USEC as the executive agent, and designating the DOE to supervise an open auction of the Russian material to bidders qualified to handle it.

Appendix A

Key Decision Documents Related to the Long-Term Storage and Disposition of U.S. Government-Owned Plutonium

National Academy of Sciences, Committee on International Security and Arms Control, *Management and Disposition of Excess Weapons Plutonium*, Executive Summary and Main Report, (Washington, D.C.: National Academy Press, 1994).

National Academy of Sciences, Committee on International Security and Arms Control, *Management and Disposition of Excess Weapons Plutonium, Reactor-Related Options*, (Washington, D.C.: National Academy Press, 1995).

DOE, Office of Fissile Materials Disposition, *Storage and Disposition of Weapons-Usable Fissile Materials, Draft Programmatic Environmental Impact Statement, Vol. 1-III*, DOE/EIS-0229-D, February 1996.

DOE, Office of Fissile Material Disposition, *Technical Summary Report For Long-Term Storage of Weapons-Usable Fissile Material*, DOE/MD-0004, July 17, 1996.

DOE, Office of Fissile Material Disposition, *Technical Summary Report For Surplus Weapons-Usable Plutonium Disposition*, DOE/MD-0003, July 17, 1996.

DOE, Office of Arms Control and Non-Proliferation, *Nonproliferation and Arms Control Assessment of Weapons-Usable Fissile Material Storage and Plutonium Disposition Alternatives*, DRAFT, October 1, 1999.

Lawrence Livermore National Laboratory, Fissile Materials Disposition Program, *Alternative Technical Summary Report: Ceramic Can-In Canister Variant*, UCRL-ID-122661, L-20219-1, August 26, 1996.

Lawrence Livermore National Laboratory, Fissile Materials Disposition Program, *Alternative Technical Summary Report: Ceramic Greenfield Variant*, UCRL-ID-122662, L-20218-1, August 26, 1996.

Lawrence Livermore National Laboratory, Fissile Materials Disposition Program, *Alternative Technical Summary Report: Electrometallurgical Treatment Variant*, UCRL-ID-122664, L-20220-1, August 26, 1996.

Lawrence Livermore National Laboratory, Fissile Materials Disposition Program, *Alternative Technical Summary Report: Vitrification Adjunct Melter to DWPF Variant*, UCRL-ID-122660, L-20217-1, August 26, 1996.

Lawrence Livermore National Laboratory, Fissile Materials Disposition Program, *Alternative Technical Summary Report: Vitrification Can-In Canister Variant*, UCRL-ID-122659, L-20216-1, August 26, 1996.

Lawrence Livermore National Laboratory, Fissile Materials Disposition Program, *Alternative Technical Summary Report: Vitrification Greenfield Variant*, UCRL-ID-122663, L-20215-1, August 26, 1996.

Joint United States/Russian Plutonium Disposition Study, September 1996.

Interim Report of the US-Russian Independent Scientific Commission on Disposition of Excess weapons Plutonium, 16 September 1996.