15. Reducing Stockpiles

The United States and Russia both maintain massive stockpiles of nuclear warheads, plutonium, and highly enriched uranium (HEU) built up over the decades of the Cold War – stockpiles far beyond any conceivable remaining military need. Reducing these stockpiles is a long-term proposition that will not address the immediate threat of theft the world faces today.[1]

The first priority must be to ensure that all of these stockpiles are secure and accounted for. (Indeed, unless extreme care is taken to provide high levels of security and accounting throughout, the transportation and processing of these materials involved in getting rid of them could temporarily increase proliferation risks.)

Nevertheless, reducing these stockpiles with all deliberate speed should remain a priority – both to send a signal to the world that U.S. and Russian arms reductions are intended to be permanent, and to avoid having to keep these stocks under heavy guard forever. The surest way to keep a kilogram of plutonium or HEU from being stolen and used by terrorists for a nuclear weapon is to destroy it – or transform it into a form extremely difficult to ever again use in a nuclear bomb. For these reasons, at their May 2002 summit, President Bush and President Putin instructed their experts to examine options for expanded disposition efforts for both plutonium and HEU.[2]

Reducing HEU Stockpiles – Maintaining the Current Agreement

The first priority in reducing HEU stockpiles must be to continue stable implementation of the existing U.S.-Russian HEU Purchase Agreement, under which the United States is purchasing 30 tons of HEU from dismantled Russian nuclear weapons each year, blended to proliferation-resistant low-enriched uranium (LEU) for use as commercial reactor fuel.

This arrangement began in 1993 (though it took some time to reach the 30-tons-per-year level); by 2013, when the current deal ends, the United States is expected to have purchased LEU from 500 tons of HEU. This is the single most important and successful U.S.-Russian cooperative effort focused on management of nuclear weapons and materials: at a single stroke, it gives Russia a financial incentive to dismantle thousands of nuclear weapons, destroys enough potentially vulnerable HEU for thousands of nuclear bombs, creates jobs for thousands of Russian nuclear workers, provides hundreds of millions of dollars a year to the hard-strapped Russian nuclear complex, and provides the United States with valuable commercial reactor fuel – all at very little net cost to the U.S. taxpayer, since it is proceeding as a largely commercial transaction. Indeed, some 10% of all the electricity used in the United States is coming from dismantled Russian nuclear weapons, since nuclear reactors provide roughly 20% of the U.S.

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[1] Two additional factors strengthen this conclusion. First is the small amount of nuclear material terrorists would need to make a nuclear bomb. With only a few kilograms needed for a bomb, whether a large central storage facility contains 50 tons of plutonium or 1 ton is far less important than how well secured and accounted for the material in that facility is – and a program that reduced the total stockpiles dramatically without actually reducing the number of facilities with enough material for a bomb, or the number of people with access to these materials, might offer very little benefit in reducing the risk of nuclear theft. Second is the high levels of security that it is possible in principle to provide for excess nuclear material: most of the 34 tons of Russian excess weapons plutonium covered in the U.S.-Russian plutonium disposition agreement, for example, will be stored until disposition in the highly secure Mayak Fissile Material Storage Facility, making it some of the lowest-theft-risk plutonium in Russia.

[2] The White House, Office of the Press Secretary, "Text of Joint Declaration" (Moscow, Russia, press release, May 24, 2002; available at http://www.whitehouse.gov/news/releases/2002/05/20020524-2.html as of January 14, 2003).

electricity supply, and roughly half of their fuel is coming from the HEU Purchase Agreement.

Unfortunately, during the agreement's history, there have been a large number of delays and disagreements over its implementation. Most recently, USEC (formerly the U.S. Enrichment Corporation), the U.S. executive agent, demanded (ultimately successfully, after a long delay) that Russia accept a new pricing approach under which USEC will pay Russia a price well below the average price USEC will receive when it resells the material. This will reduce the amount paid to Russia by several tens of millions of dollars a year, compared to the previous pricing structure, and has provoked significant resentment among some Russian nuclear officials. Nevertheless, for now, deliveries are stabilized, and USEC now has a substantial profit incentive to carry out the deal as rapidly as possible, the Russian material now being by far its lowest-cost source of supply.

For the future, the reserve stockpile of LEU blended from HEU that the U.S. government has agreed to purchase over the next decade should provide a useful backup in the event of another substantial interruption of supply. In the longer term, if problems again arise with USEC as the executive agent, the U.S. government should keep the option of other executive agent arrangements open – including the possibility of designating multiple executive agents, who could compete with each other to buy the Russian material, guaranteeing Russia a fair market price by the free play of competition.[3]

Recommendation: ***Maintain and stabilize implementation of the U.S.-Russian HEU Purchase Agreement, including purchasing a stockpile of blended material to cover interruptions in deliveries, and leaving open the option to designate additional executive agents if necessary.***

Reducing HEU Stockpiles – An Accelerated Blend-Down Initiative

The current 30-tons-per-year rate at which Russian HEU is being blended was set by what the market would bear, not by what the national security demands. From a security perspective, it would be highly desirable to destroy every kilogram of excess HEU everywhere in the world as rapidly as possible. Russia's uranium processing facilities are believed to be capable, with the addition of only a few pieces of equipment, of blending 60 tons of HEU each year, rather than 30. This much larger amount of material could not simply be sold on the market without crashing prices and disrupting the existing 30-tons-per-year deal. But as a security investment, the United States and the other participants in the G-8 Global Partnership could pay Russia to blend an additional 30 tons each year and keep it off the market, in monitored storage, until the existing deal is complete. We described such an accelerated blend-down approach in detail in our previous report.[4] If the blending rate were doubled, more than a thousand bombs' worth of additional HEU would be destroyed every year – clear, measurable threat reduction for each dollar invested. Russia is thought to have begun the deal with some 1,100 tons of HEU, so selling 500 tons would leave 600 tons remaining – though Russia has been blending

[3] For a discussion of the multiple agent approach, see Thomas L. Neff, "Decision Time for the HEU Deal: U.S. Security vs. Private Interests," *Arms Control Today* (June 2001); for a discussion of the virtues of having a buffer stockpile to address disruptions, see Thomas L. Neff, "Accelerated Blend-Down of HEU" (unpublished paper, Massachusetts Institute of Technology, October 2000).

[4] See Matthew Bunn, John P. Holdren, and Anthony Wier, *Securing Nuclear Warheads and Materials*: Seven Steps for Immediate Action (Washington, D.C.: Nuclear Threat Initiative and Project on Managing the Atom, Harvard University, May 2002; available at http://www.nti.org/e_research/securing_nuclear_weapons_and_materials_May2002.pdf as of February 25, 2003), pp. 65–72; also Robert L. Civiak, *Closing the Gaps: Securing High Enriched Uranium in the Former Soviet Union and Eastern Europe* (Washington, D.C.: Federation of American Scientists, May 2002; available at http://www.fas.org/ssp/docs/020500-heu/full.pdf as of January 14, 2003); Jeffrey Boutwell, Francesco Calogero, and Jack Harris, *Nuclear Terrorism: The Danger of Highly Enriched Uranium (HEU)* (Washington, D.C.: Pugwash Conference on Science and World Affairs, September 2002; available at http://www.pugwash.org/publication/pb/sept2002.pdf as of February 25, 2003); for an earlier discussion of the concept, see Neff, "Accelerated Blend-Down of HEU," op. cit.

a modest amount of additional material in commercial deals outside the HEU Purchase Agreement, and using some in military, icebreaker, and research reactors. It seems unlikely that Russia will need more than 200 tons for its military programs, meaning that under the right circumstances, hundreds of tons will be available for blending and eventual sale.[5]

The working group that resulted from the May 2002 Bush-Putin summit quickly prepared an initial report that examined a variety of options for modestly sized additions to the current HEU purchase agreement.[6] The most important of these was the possibility, just mentioned, of blending down a limited additional amount of material which could be stored as a "buffer stock" in the United States, to be used in the event of a disruption in the supply of LEU from the HEU deal. The Bush administration has requested $30 million in fiscal year (FY) 2004 to finance the first year of a decade-long purchase of such a buffer stock, along with the other modest blending initiatives outlined in the joint summit report. At that time, the Russian side was not ready to officially explore a large-scale accelerated blend-down initiative. Immediately after the completion of the government-to-government study, however, Russia's Ministry of Atomic Energy (MINATOM) agreed to move forward with a study sponsored by the private Nuclear Threat Initiative looking at options for large-scale accelerated blend-down.[7]

There are a variety of reasons why Russia's Ministry of Atomic Energy may be less than enthusiastic about pursuing such a large-scale accelerated blend-down initiative. These include concerns over whether it will be possible to sell the extra material when the current deal expires, lack of confidence in future U.S. willingness to abide by commitments to reasonable commercial terms (given past U.S. shifts in its approach to the existing HEU Purchase Agreement), concerns over the political implications of agreeing to sell off another large piece of Russia's nuclear stockpile, lack of interest in an arrangement that provides more jobs and revenue for facilities that already have plenty of jobs and revenue under the existing HEU deal, and the like.[8]

At the same time, destroying nuclear material that might otherwise be vulnerable to terrorist theft is as much in Russia's interests as it is in the U.S. interest, and reducing the quantity of HEU that had to be guarded to stringent standards would reduce Russia's security costs. Some senior Russian experts have endorsed such an initiative as an important next step in U.S.-Russian nuclear security cooperation.[9]

To be successful, a deal will have to be structured that clearly serves Russia's interests as well as international interests in destroying HEU. Such an arrangement is clearly possible; the key question is what combination of price and other arrangements would ensure that the answer was not "nyet" but "da."

To move this effort forward, the United States should begin a serious exploration with Russia of the circumstances under which it might be willing to agree to a large-scale accelerated blend-down of

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[5] If, on average, maintenance of each warhead requires 30 kilograms of HEU (including material in the warhead and material in various stages of the warhead support "pipeline"), then a stockpile of 5,000 nuclear warheads – substantially more than either the United States or Russia realistically needs – would require 150 tons of HEU. Another 50 tons of HEU would provide naval fuel for decades.

[6] Secretary of Energy Spencer Abraham and Minister of Atomic Energy Alexander Rumiantsev, "Joint Statement" (press release, Washington, D.C., September 16, 2002).

[7] Discussions with Nuclear Threat Initiative personnel. (Bunn is a paid consultant to the Nuclear Threat Initiative, working on this project among others.)

[8] For a comprehensive discussion, see Thomas L. Neff, "Accelearating Russian Fissile Material Disposition" (paper presented at the 9th Annual International Nuclear Materials Policy Forum: The Disposition Stewardship, and Utilization of Weapons Grade Material and Spent Fuel, Washington, D.C., July 11, 2002).

[9] See, for example, John P. Holdren and Nikolai P. Laverov, *Letter Report From the Co-Chairs of the Joint Committee on U.S.-Russian Cooperation on Nuclear Non-Proliferation* (Washington, D.C.: The National Academies, December 4, 2002; available at http://www4.nationalacademies.org/news.nsf/isbn/s02052003?OpenDocument as of February 25, 2003)

HEU. In particular, the United States and the other participants in the G-8 Global Partnership should consider approaches that might be able to leverage more than just the destruction of additional HEU: for example, if the payment for accelerated blend-down were in the form of a pre-payment against future deliveries (which would help convince Russia that the United States would have a strong incentive to help get the material onto the market in the future, allowing Russia ultimately to receive its full commercial value), the pre-payment might be designed to be larger than the actual cost of the blending, with an understanding that the additional funds would be spent on securing nuclear materials, shrinking Russia's nuclear complex, and providing jobs for excess nuclear personnel.[10]

As it did in 1998 to facilitate negotiation of a plutonium disposition agreement, Congress should provide an appropriation to pay for the blend-down and incentives that may be negotiated as part of the package (amounting to perhaps $50 million for the first year), conditional on negotiation of an accelerated blend-down agreement. Having such conditionally appropriated funds makes U.S. commitments to pay for such initiatives much more credible, and greatly facilitates negotiation.

Recommendation: ***Reach agreement with Russia on an "accelerated blend-down" initiative, paying Russia a fee to blend additional HEU to non-weapons-usable levels and store it for later sale when the market is ready.***

Expanded Disposition of Excess Plutonium

Ironically, disposition of excess plutonium is a long-term issue on which urgent action is needed. The program successfully made the case for a substantial and long-term budget increase in the Bush administration's threat reduction policy review in 2001, and won support for that increase from Congress. Then, in 2002, the program gained renewed international support as one of the priority items for expenditure of the $20 billion pledged in the G-8 Global Partnership. If, following both of these victories, the program does not make substantial headway toward putting realistic financing arrangements in place and moving toward actual construction of facilities during 2003 – after nearly a decade of attempts to move this effort forward – officials and legislators in Washington, Moscow, and other capitals are likely to begin to lose faith that this effort will ever move forward. The current momentum, if lost, would be very difficult to regain – with the result that enough excess weapon-grade plutonium for many thousands of nuclear weapons will simply remain in storage, in forms readily usable in new nuclear bombs.

To keep the momentum, to ensure that disposition goes forward on a scale large enough to matter, to guarantee security throughout the process, to and provide backups should the present strategy fail, the United States should:

- **Press hard to complete during 2003 both an international agreement on financing and management and a clear, implementable work plan with Russia.** Currently, the plan is to burn U.S. and Russian excess weapons plutonium as fuel in existing nuclear power plants in the United States and Russia (possibly supplemented by plants in Europe), primarily in light-water reactors. Toward that end, the United States proposes to construct very similar plutonium fuel fabrication plants in the United States and Russia. The United States would pay 100% of the cost of disposition of its own weapons plutonium, while contributing to an international consortium that would cover the estimated $2 billion cost of disposition of 34 tons of Russian weapons plutonium. The countries contributing to the international consortium would also participate in the management and implementation of the project. International discussions intended to pull together such a consortium have been underway for several years, and a number of countries have pledged at least modest contributions, but no final arrangement has yet been reached. Similarly, U.S.-Russian discussions are still underway concerning exactly how all the steps toward burning this plutonium as fuel would be completed – how much plutonium will be burned in which reactors, starting when; what process has to be followed for getting approvals and licenses to build a plutonium

[10] The authors are greatful to Thomas L. Neff of MIT for discussions of the virtues of such an approach.

fuel fabrication plant; how the plutonium fuel's safety when used in existing reactors will be confirmed and licensed; and so on. A particularly important activity, for the current strategy, is planning for enough reactor capacity to meet the goal, specified in the U.S.-Russian agreement, of being able to burn 4 tons of plutonium a year. Given the modest number of modern and relatively safe reactors in Russia, meeting this goal will require either substantial modifications to these reactors to enable them to burn more plutonium, use of additional reactors outside of Russia, or use of newly constructed reactors as well.

In both these areas, therefore, a substantial effort is needed to reach agreement during 2003, so that real movement toward building the needed facilities and ultimately carrying out disposition of excess plutonium can begin. Russia's Ministry of Atomic Energy continues to feel no urgency to move forward quickly with disposition of excess plutonium. Therefore, if progress is to be made, careful attention will have to be paid to structuring approaches that provide Russia a substantial incentive to agree. The international consortium, for example, might potentially be structured in a way that Russia saw as allowing it to build up long-term commercial partnerships with Western firms in the world nuclear fuel market. However, if it is proving difficult to work out an effective multilateral financing and management arrangement for plutonium disposition even as the other participants in the G-8 Global Partnership are making contributions to other threat reduction efforts on the scale pledged, the United States should consider paying for Russian disposition itself, as part of its contribution to the Global Partnership, simplifying management substantially by making the project bilateral rather than multilateral.[11]

- **Begin now to discuss going beyond the 34 tons of plutonium on each side addressed in the initial U.S.-Russian plutonium disposition agreement.** Disposition of 34 tons of excess weapons plutonium in Russia, and 34 more in the United States, will be a very important and useful first step toward disposition of substantially larger quantities of material – but only if it is a first step. The material slated to be used as fuel in the U.S.-Russian disposition agreement (34 tons of weapons plutonium plus 2 tons of reactor-grade plutonium) represents roughly one-fifth of the total Russian stockpile of separated plutonium. (The U.S. 34 tons represents about one-third of its plutonium stockpile.) The material not covered by this agreement is more than enough to pose huge risks of theft if not properly secured, or to allow a return to Cold War levels of armament should political circumstances change. If the United States, Russia, and the rest of the international community get a 34-ton program going and then walk away without addressing the larger picture of excess plutonium, the 34-ton program will have had little benefit – either for reducing the risk of plutonium theft, or for ensuring that nuclear arms reductions would be difficult and costly to reverse.

  Hence, the United States and Russia should begin discussions now on declaring additional material excess to their military needs, and should structure plans for the disposition program to ensure that the program, once underway, could handle much larger quantities of plutonium than are covered under the initial agreement. If all effort continues to focus on the initial 34 tons of plutonium on each side, policymakers in the participating countries are likely to lose sight of the need to deal with much larger quantities of plutonium. As a result, the financing and technical plans for disposition will wind up sized in a way that is not readily expandable to cope with additional material. This discussion of declaring additional plutonium excess should be in the context of the broader discussion recommended above dealing with what nuclear complexes and stockpiles each side needs to maintain.

  Expanded disposition of plutonium was among the subjects of the statement from the May 2002 Bush-Putin summit, but the working group that followed up that statement did not reach

[11] In the past, bilateral threat reduction projects have had a substantially better track record of success than have multilateral projects.

any agreements on including additional material in the two sides' plutonium disposition programs. Nevertheless, Russia already has a large amount of additional material which it has formally committed never to use in weapons, including a total of 50 tons of plutonium from dismantled weapons, 32 tons of separated civilian plutonium, and all the weapons plutonium produced since 1994. All this material sums to a total currently in the range of 90 tons, slightly more than half of its total separated plutonium stockpile.[12] The United States has also declared 52.5 tons of plutonium, slightly more than half of its government stockpile, excess to its military needs. Even these figures should be considered initial goals, however: much of the remaining plutonium not yet declared excess is not in fact needed for any plausible military purpose. Ultimately, the United States and Russia should agree to reduce their nuclear warhead stockpiles to the lowest possible levels consistent with their military security, and to reduce their plutonium and HEU stockpiles to the levels needed to support those low, agreed warhead stockpiles.

- **Begin now to plan in detail for maintaining very high levels of security and accounting throughout the disposition process.** Nuclear material is more difficult to secure and account for when it is being transported and processed in bulk than when it is being stored at a secure storage facility. Hence, to ensure that disposition of excess plutonium in fact reduces the threat of nuclear theft over the long term rather than increases it, it will be essential to ensure that very high levels of security and accounting are maintained throughout the process. The theft of nuclear material from a process that was only taking place because of U.S. and international support provided to promote arms reduction and nonproliferation – causing, rather than preventing proliferation – would not only be a security disaster, but also a political catastrophe for the entire threat reduction effort. Achieving the needed levels of security and accounting for nuclear material will be more difficult and more costly if such issues are dealt with as an add-on after the entire approach has been designed. It would be much better to design them in from the outset, and the United States should initiate discussions with Russia and its other international partners to do so.

- **Initiate discussions of a "plutonium swap" approach, using existing plutonium fuel fabrication facilities and reactors already burning plutonium fuel, as a complement or alternative to the current plan.** Today, some 10 tons of reactor-grade civilian plutonium is already being burned as fuel for civilian power reactors each year. By far the fastest and cheapest approach to reducing stockpiles of excess weapons plutonium, if agreement could be reached on it, would be to substitute excess weapons plutonium for this civilian plutonium, thereby burning some 10 tons a year of excess weapons plutonium while using existing fuel fabrication facilities and contract arrangements.[13] The excess weapons plutonium would be converted to oxides suitable for fuel fabrication in Russia and the United States, and shipped to existing European fuel fabrication facilities under heavy guard. Modest license modifications for those facilities and for the reactors that use fuel from them would likely be needed in order for them to use weapon-grade rather than reactor-grade plutonium. The civilian plutonium that would have been burned at a rate of 10 tons per year would be displaced and would build up in storage, adding to the large quantities of civilian separated plutonium that are already in storage. In effect, this would transform a problem of excess weapon-grade plutonium in Russia and the United States, under no international safeguards, to a problem of excess reactor-grade plutonium stored in secure facilities in Europe under international safeguards – a significant improvement, though not a complete solution to the problem by any means. These stockpiles of displaced civilian plutonium could be "swapped" for the excess weapons plutonium, so that the United States and Russia would retain title to the same amount of fissile plutonium they each sent to Europe (potentially important for Russia, which focuses more on the potential future value of plutonium than on

[12] See Bunn, *The Next Wave*, pp. 54–55.

its present liabilities). Indeed, given the costs and difficulties for utilities in managing plutonium, the European and Japanese utilities that own the huge stocks of separated civilian plutonium now in storage would likely be happy to have Russia take title to two tons of civilian plutonium for every one ton of weapons plutonium sent to Europe. The United States should initiate discussions of such a "plutonium swap" approach, but should pursue them carefully, making sure not to disrupt current plutonium disposition plans.

- **Continue to pursue options for burning part of Russia's excess plutonium in reactors outside of Russia, including through leasing arrangements.** As already noted, without substantial modifications, Russia's existing modern reactors alone are not enough to burn four tons a year, the target specified in the U.S.-Russian plutonium disposition agreement. Europe's reactors already licensed to burn plutonium fuel already have more civilian plutonium than they can handle, unless some kind of substitution arrangement like that just described can be worked out. Nonetheless, for some years there have been quiet international discussions of possibilities for burning some of Russia's excess weapons plutonium in reactors in other countries, and there are at least a few reactors that could be possibilities – particularly if their incentive to use this fuel was increased by having the fresh fuel service packaged with the service of taking the spent fuel back to Russia, in a fuel "leasing" arrangement. In addition to Western Europe, there is Ukraine, where 11 VVER-1000s, the most modern Soviet reactor design, are already operating, and already receive their fuel from Russia. There is also Canada, whose CANDU reactors have also been explored as possibilities for burning excess weapons plutonium. The United States and Russia should continue discussions with these other countries, in pursuit of ways to accelerate the disposition of Russia's excess weapons plutonium.

- **Restart development of plutonium immobilization technologies.** The plutonium disposition program currently has no backup option ready should its current focus on burning plutonium as fuel in existing reactors encounter serious obstacles. Yet there is a substantial risk that major obstacles will arise. The current approach faces intense political opposition from U.S. non-governmental organizations that question its safety and security, and are concerned that it will encourage the use of plutonium fuel elsewhere. And the structure of the U.S. legal and regulatory system offers opponents many opportunities to attempt to stop or delay new nuclear projects, all of which are they are likely to exploit. The approach faces similar opposition from environmentalists in Russia, and while the opportunities for opponents to block or delay projects are fewer there, the Ministry of Atomic Energy is only lukewarm about moving the project forward. What is more, it may prove to be impossible to work out an approach that convinces Russian regulators that Russia's Soviet-designed reactors can in fact burn plutonium fuel safely – or at least impossible to do so without substantial delays. Any significant accident or security incident with plutonium fuel fabrication or use in a reactor could potentially stop the program in its tracks, either politically or technically.

  In short, it would make sense to have a fallback approach in development. Until it was effectively canceled, such an alternative was provided by technology for immobilizing plutonium with high-level

[13] This approach was outlined in Thomas L. Neff, "Perspectives on Actions Necessary to Move the Plutonium Disposition Program Forward" (paper presented at the International Policy Forum: Management and Disposition of Nuclear Weapons Materials, Bethesda, Maryland, March 23–26, 1998). Senator Pete Domenici (R-NM) championed the idea briefly, but dropped it after finding little European interest (see, for example, Dave Airozo, "Finding Europeans Disinterested, Domenici Shelves `Global Burn'," *Nuclear Fuel*, July 27, 1998). If appropriately presented and packaged with reasonable incentives for all concerned, however, this approach could be designed so that it would not interfere with European fuel-cycle choices, but, indeed, would effectively lock in use of plutonium fuel for a decade or more as part of a nuclear arms reduction initiative. A similar approach was also discussed in U.S. National Academy of Sciences, *Management and Disposition of Excess Weapons Plutonium*, op. cit., pp. 176–181.

wastes – creating massive, intensely radioactive objects quite similar in their proliferation characteristics to spent fuel from nuclear power plants. Indeed, to avoid putting all the plutonium disposition eggs in one basket, a panel of the National Academy of Sciences recommended that the U.S. and Russian programs pursue both technologies at the same time, as did a group of senior U.S. and Russian experts asked to advise their two Presidents on plutonium disposition in the late 1990s. For the U.S. program, some means of dealing with the tons of highly contaminated plutonium unsuitable for making into fuel is likely to be needed, and immobilization appears to be the best approach.[14] While the Russian government has traditionally opposed plutonium immobilization on the grounds that it would throw away a material that cost an enormous amount to produce and may be valuable in future, carrying out joint research and development on immobilization approaches could help build up the cadre of experts in Russia who understand immobilization and its potential value – a value which may become more apparent to Russian officials if the costs and difficulties of the plutonium fuel approach continue to escalate in the future. Moreover, if cost estimates for the plutonium fuel option continue to rise, it is conceivable that the option of buying Russia's excess plutonium and then paying to have it immobilized will ultimately prove to be competitive. In short, it is time for the United States to restart at least a modest research and development effort on plutonium immobilization, and restart joint development with Russia.[15]

- **Advanced reactors and fuel cycles.** Since existing reactors and demonstrated fuel approaches are available, disposition of excess weapons plutonium should not wait for (or pay much of the costs of) the development, licensing, and construction of new types of reactors (such as high-temperature gas-cooled reactors or new liquid-metal cooled reactors) or the development, licensing, and implementation of new fuel types (such as proposed thorium-plutonium-uranium fuels). But such new reactors and fuel types may well be promising subjects of research and development for the future of nuclear energy. A modest joint U.S.-Russian cooperative program to develop such advanced concepts – including, as much as possible, the participation of former nuclear weapons experts who are no longer needed – would make sense, as an item to be funded separately from disposition of excess weapons plutonium. Should such new reactors or fuels be developed and become available while there is still excess plutonium that needs to be eliminated, their use for disposition of that plutonium should certainly be considered.

- **Consider options for purchasing excess Russian plutonium.** There are a variety of possible approaches worth considering for simply purchasing Russia's excess weapons plutonium – as the United States is now purchasing HEU from dismantled Russian weapons. If Russia were willing to sell (senior Russian officials have said different things on this point at different times) the cost would likely not be astronomical. If the buyer – the United States or other countries participating in the G-8 Global Partnership – were willing to pay the same amount per ton as the United States is now paying for HEU, then 50 tons plutonium (enough for over 10,000 nuclear weapons) would cost just over $1 billion.[16] This would be a generous offer, since in the current market the plutonium's actual commercial value is negative (the costs of securing it and making fuel from it are much higher than the value of the fuel). The buyer, however, would presumably then have the right to remove the material from Russia for immobilization or use as

[14] These materials have been transferred out of the responsibility of the U.S. plutonium disposition program, to the Department of Energy's (DOE) Office of Environmental Management, but they still must be addressed, as part of a comprehensive approach to managing U.S. plutonium stockpiles.

[15] There is a vast literature of articles from opponents of plutonium fuel use making the case for immobilization; for a representative one, see Allison Macfarlane and Adam Bernstein, "Russia's Nukes: Canning Plutonium – Faster and Cheaper," *Bulletin of the Atomic Scientists* 55, no. 3 (May/June 1999; available at http://www.thebulletin.org/issues/1999/mj99/mj99mcfarlane.html as of January 14, 2003).

[16] The original estimated price for 500 tons of HEU was $12 billion, but the price of enrichment work has declined since then, reducing the price-per-ton of HEU.

fuel elsewhere, or to pay for it to be immobilized or used as fuel within Russia. In the case of a U.S. purchase, for example, it might be possible to build only one plutonium fuel fabrication plant, rather than one in the United States and one in Russia. There are a wide range of difficult political and legal questions that would have to be addressed – along with some technical and economic questions – before such a purchase could become a reality, but it remains something that should be considered. The option may be particularly valuable if the current plan to use plutonium as fuel runs into serious obstacles or cost overruns, while Russia continues to resist throwing its plutonium away through immobilization. In that case, the option of purchasing Russia's plutonium (thereby allowing Russia to monetize it immediately), and then paying for it to be immobilized, might provide a plausible back-up approach. As with the "swap" concept, however, considerable care must be used to explore these concepts without undermining the main thrust of the plutonium disposition program, which remains focused on using the material as fuel while it remains under the control of its original owners, Russia and the United States.

A somewhat similar proposal is to offer a substantial financial incentive, perhaps $10,000 per kilogram ($500 million for 50 tons) for Russia to deposit its plutonium in a facility in Russia with international (rather than purely national) guards and monitors, and, for reciprocity, have the United States deposit its excess plutonium in a facility in the United States under similar arrangements.[17] A more radical idea is to set up a single facility in some third country, where all the U.S. and Russian excess material – and perhaps excess warheads as well – would be stored.[18] Obvious obstacles to that concept include obtaining the agreement of Russia, the United States, and the third country.

Recommendation: ***Move ahead with the currently planned approaches to disposition of excess weapons plutonium.***

Recommendation: ***Seek to reach agreements by the end of 2003 on a financing and management arrangement, and a step-by-step work plan, for disposition of Russian excess weapons plutonium.***

Recommendation: ***Begin now to discuss going beyond the 34 tons of plutonium on each side covered by the U.S.-Russian Plutonium Disposition and Management Agreement.***

Recommendation: ***Begin now to plan in detail for maintaining very high levels of security and accounting throughout the disposition process.***

Recommendation: ***Continue exploring complements or alternatives to the current approach to plutonium disposition, including:***

- ***Initiate discussions of a "plutonium swap" approach, using existing plutonium fuel fabrication facilities and reactors already burning civilian plutonium fuel, which could burn weapons plutonium fuel instead.***
- ***Pursue options for burning part of Russia's excess plutonium in reactors outside of Russia, including through leasing arrangements.***
- ***Restart development of plutonium immobilization technologies.***
- ***If advanced reactors and fuel cycles are developed and built for other purposes, consider their use for disposition of whatever excess plutonium remains at that time.***
- ***Consider options for purchasing Russian excess plutonium stockpiles.***

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[17] For a description of this "plutonium bank" idea, see Ashton B. Carter and Owen Coté, "Disposition of Fissile Materials," in Graham Allison, Ashton B. Carter, Steven E. Miller, and Philip Zelikow, eds., *Cooperative Denuclearization: From Pledges to Deeds*, CSIA Studies in International Security No. 2 (Cambridge, Mass.: MIT Press, 1993).

[18] See Brian Chow, Richard H. Speier, and G.S. Jones, *A Concept for Strategic Material Accelerated Removal Talks*, DRU-1338-DOE (Washington, D.C.: RAND Corporation, 1996).