The Future of Plutonium

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A. Introduction

Beyond trace amounts in uranium ore deposits, plutonium is anthropogenic in origin, so its existence and quantities are determined by its production and utilization since the 1940s. Plutonium has two major applications—as a nuclear explosive material and as a nuclear reactor fuel—and one minor application where the isotope Pu-238 is highly concentrated—as a source material for radioisotope thermoelectric generators and heater units. These applications are reviewed below.

B. Plutonium as a Nuclear Explosive Material

Today eight countries possess nuclear weapons—the United States, Russia, the United Kingdom, France, China, Israel, India and Pakistan. The first five of these countries are signatories of the Nuclear Nonproliferation Treaty (NPT). The parties have an obligation under Article VI of the NPT:

> "to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament, and on a treaty on general and complete disarmament under strict and effective international controls"

To meet this obligation there are two categories of activities that have to be undertaken: a) political steps designed to reduce incentives to acquire and accumulate nuclear weapons and threaten their use, and b) technical steps to eliminate existing arsenals and increase the time it takes to reconstitute them or acquire new ones. With regard to the technical measures it is important to recognize that our NPT obligations are not limited to the elimination of nuclear warheads themselves. If a nation disassembles an arsenal of nuclear warhead and stores the critical components, the effect is only to marginally increase the time it takes to use them. A more useful parameter for measuring progress in achieving nuclear disarmament is the availability of deliverable warheads over time. Thus, the parties must reduce the number of nuclear warheads:

a) on launch ready alert;
b) on generated alert;
c) in the active stockpile;
d) in the inactive stockpile; and
e) awaiting dismantlement.

And reduce the stockpile of weapons-usable fissionable materials:

f) in weapon component form, e.g., pits
g) in strategic reserves; and

h) in separated forms.

The lack of progress made by the United States and Russia in achieving meaningful reductions in most of these categories is evidence that neither country is making a good faith effort to meet its NPT obligation under Article VI.

To meet its treaty obligations there are several steps the United States should take immediately and unilaterally:

(1) stop specifically targeting Russia and other countries with nuclear weapons, which requires abolition of the SIOP as it is currently understood and implemented, and in the near-term, creation of a capability to quickly generate a set of contingency war plans if needed;
(2) take all U.S. land-based ICBMs off alert;
(3) ratify the Comprehensive Test Ban Treaty (CTBT);
(4) redirect and scale back the Stockpile Stewardship and Management Program (SSMP) to focus on acquiring the capability to remanufacture existing, well-tested designs to original specifications, as required; and
(5) permanently close the Nevada Test Site;

In addition, the United States should seek on a bilateral or multilateral basis:

(6) much deeper reductions in U.S. and Russian strategic arsenals below the 2,000-2,500 accountable strategic warheads that United States is proposing under START III;
(7) the elimination of all non-strategic nuclear warheads, all reserve warheads and all strategic reserves of fissile materials;
(8) public declarations of all nuclear weapon and fissile material stockpiles and their production histories, and cooperative verification measures to confirm data included in these declarations and data exchanges;
(9) more informal transparency measures such as site visits, scientific exchanges, and cooperative programs between organizations involved in sensitive nuclear activities;
(10) verified dismantlement of warheads and monitored interim storage of their fissile material components;
(11) increased security and safe disposition of existing stocks of weapon-usable materials;
(12) verified storage and disposition of highly-enriched uranium and plutonium declared to be in excess of national security needs; and
(13) continued assistance to Russia in downsizing Russia's nuclear weapons complex, and new alternative employment opportunities for workers in Russia's nuclear weapon complex.

I will briefly elaborate on these initiatives:

1. Stop targeting Russia and other countries with nuclear weapons.

The process and act of targeting defines an enemy or enemies. The Single Integrated Operational Plan (SIOP) has evolved over four decades but it is still grounded in the basic assumption that the United States needs a permanent, in-place war plan directed against the enemy--formerly the Soviet Union, and today, Russia. Statements about Russia as economic partner are in conflict with the reality that it is targeted by thousands of U.S. nuclear weapons. Reductions in the nuclear force levels continue to be dependent upon the calculus of targeting and the needs of the war plan rather than the other way around. Current START III proposals for smaller forces (either 2500 or 1500 warheads) that remain grounded in the basic SIOP assumptions are not fruitful avenues to pursue. Something much more fundamental must occur. The United States should abolish the SIOP as it is currently understood and implemented. Force requirements must be decoupled from the current plans that include major attack (including first strike) options based on unrealistic contingencies. Under new guidance the United States should not target any country specifically but create the capability to quickly construct contingency war plans if needed.

2. Take all U.S. ICBMs off alert.

The Soviet Union collapsed in late-1991. The Cold War is over. The United States is at peace with Russia; there are some 100,000 American citizens in Russia at any given time; and American companies are trying to invest in Russia. The idea that the United States needs to keep over 95 percent of the 550 ICBMs on alert, ready to retarget and fire at Russia within a few minutes is ludicrous.

3. Ratify the Comprehensive Test Ban Treaty (CTBT).

The CTBT has been ratified by Russia, but not by the United States. After agreeing in the summer of 1995 to support the CTBT in exchange for a $4 billion per year science-based stockpile stewardship program, the directors of the three U.S. nuclear weapon laboratories subsequently testified on October 7, 1999, before the Senate Armed Services Committee that the future capability of the stockpile stewardship program to maintain the nuclear arsenal without testing could not be guaranteed.

> **John Browne (LANL):** "Although we keep adding new tools each year, the essential tool kit for stockpile stewardship will not be complete until sometime in the next decade."
>
> "What is the trip wire that would cause us to recommend a test? How will we know that an issue is beyond the ability of our computational and experimental tools to resolve? We're working on this

problem. We do not have the definitive answers to these questions as yet…"

"…we can't predict that by such and such a date, we will know everything we need to know. It's an evolving process. Each year you learn something else."

Bruce Tarter (LLNL): "I think the challenge lies in the longer term….if I had one simple phrase, I think that the Stewardship Program with sustained support, is an excellent bet but it ain't a sure thing."

"I think we have a challenging program, one that's very difficult to achieve. [The Administration and the Congress] have not quite met what we said was necessary to achieve the program on the timescale that we believed was necessary in view of the aging of the designers and of the weapons."

Paul Robinson (SNL): ". . . to forego testing is to live with an uncertainty. And the question is, what is the risk, can one bound the uncertainty, and how does that work out? My statement describes the work involved in attempting to substitute Science-based Stockpile Stewardship. It is an enormous challenge, but I agree, much very good work has been done. Much has been accomplished. But we still cannot guarantee that we will ultimately be successful."

". . . We kept stressing to the White House, we can't be sure that science-based stockpile stewardship will mature in time to handle a serious safety or reliability problem as these weapons age. Without it, *without the ability at that point to test, we would be powerless to maintain the U.S. first line of defense, its strategic deterrent force* (emphasis added.)"

A week later the Senate voted 51 to 48 against CTBT ratification, largely along party lines. What shameful behavior by the lab directors.

4. Redirect and scale back the Stockpile Stewardship and Management Program (SSMP) to focus on acquiring the capability to remanufacture existing, well-tested designs to original specifications, as required.

Under the $4.5 billion per year SSMP Los Alamos National laboratory is planning to construct a $1.6 billion Advanced Hydro Test Facility to perform full scale implosions of Pu-242 pits with a multiple-view diagnostic capability and built in plutonium processing. The objective of the Accelerated Strategic Computing Initiative (ASCI), another key component of the SSMP, is to provide the numerical simulation capability to model the performance of a complete nuclear weapon from start to finish. The program seeks to have a 100 teraflop (trillion floating-point operations per second) machine by 2004—followed by a 500 teraflop machine on the drawing boards—to provide three

dimensional calculations of weapon performance with minimal reliance on the ad-hoc parameters, of "fudge factors" that characterize existing weapon codes. These are but two of the numerous new facilities and programs publicly advertised as needed to maintain the safety and reliability of existing weapons. The not-so-well hidden dual purpose of the SSMP is to achieve a "computational weapons testing—virtual testing—capability as part off a long range strategy to move nuclear design from a test-based to a simulation-based approach, giving the United States the capability to certify new nuclear weapon designs without testing.

The stewardship program should be scaled back and limited to finding ways to maintain a set of well-tested nuclear designs, without the emphasis on increasing our understanding of nuclear weapon explosion phenomena and on providing the capability to develop and certify new nuclear weapons without testing.

5. Permanently close the Nevada Test Site.

While France has permanently closed its test site in the Pacific, the United States and Russia at the Nevada Test Site (NTS) and Novaya Zemlya, respectively, conduct nuclear weapon experiments and maintain a breakout capability to resume nuclear testing. The United States should unilaterally stop sub-critical testing at NTS and other activities such as the construction of the ATLAS pulsed-power machine and high explosive experiments at BEEF, prepare to close NTS, and negotiate with Russia the joint permanent closure of these two test sites. This would have the added benefit of making the CTBT easier to verify and consequently easier to achieve Senate ratification of the CTBT. Both countries should permit international observers to confirm that no experiments result in critical or supercritical chain reactions at experimental facilities restricted to above ground.

6. Much deeper reductions in U.S. and Russian strategic arsenals.

While the Russians would like to reduce to 1500 accountable strategic warheads under START III, the United States is holding out for retention of 2000-2500 accountable warheads. Testifying before the Senate Armed Services Committee on May 23, 2000, Chairman of the Joint Chiefs General Shelton stated:

> …the bottom line is as you start to come down [in numbers of nuclear weapons] you need to make sure that you have taken a look, a hard look at the guidance that is given to go with those numbers, and also that you have the underlying analysis that you had in fact war gamed against a potential adversary to ensure that those things that are near and dear to our citizens, specifically to the Joint Chiefs for our national security, are in fact taken into account. … we feel very comfortable with the Helsinki framework that has been laid out. If we wanted to depart from that framework in any way, then we need to pause and do the necessary review, the necessary

> analysis, to ensure that any departure from that framework show that our national security in fact is as good as it is today or enhanced.

In other words, the Joint Chiefs offered the lame excuse that they were not prepared to recommend a reduction to 1500 accountable strategic warheads because they had not adequately studied the implications of doing so.

7. The elimination of all non-strategic nuclear warheads, all reserve warheads and all strategic reserves of fissile materials.

The last reductions in non-strategic nuclear warheads were the unilateral declarations made by Presidents Bush and Gorbachev in September and October 1991. President Clinton has not made any progress in this area beyond implementing the warhead dismantlements called for by President Bush. Even under START II the United States will retain some 2500 hedge warheads, and some 2500 to 3000 inactive reserve warheads for a total assembled warhead inventory approaching 10,000 warheads, plus an additional strategic reserve of about 5000 assembled pits and thermonuclear secondaries. The Russian inventories of warheads and strategic fissile material reserves are even larger.

8. Public declarations of all nuclear weapon and weapon-usable fissile material stockpiles and production histories, and cooperative verification measures to confirm data included in these declarations and data exchanges.

The United States has not pressured Russia to resume negotiations to achieve stockpile and fissile material declarations since Russia cut off negotiations in 1995. The United States apparently has linked resumption of these negotiations to the START III negotiations and refuses to make public its position on what data should be exchanged under START III. The U.S. position on warhead declarations under START III is inadequate, reflecting the continued refusal of the Department of Defense to declare inventories of U.S. deployed warheads.

9. More informal transparency measures.

High level U.S.-Russian transparency commitments made between 1994 and 1997 have been bogged down for three years and no resumption is in sight. Efforts to achieve greater transparency measures are now further hampered by new security measures imposed after the recent revelations regarding inadequacies in measures to protect nuclear weapon design information at the national laboratories.

10. Verified dismantlement of warheads and monitored interim storage of their fissile material components.

The Department of Energy (DOE) has not tasked any of the national weapon laboratories to develop a comprehensive warhead and fissile material verification protocol that the labs would deem as adequate. A decade after the collapse of the Soviet Union the DOE does not know what an adequate warhead verification program would look like.

In June 1992, the United States and Russia agreed to construct a Fissile Material Storage Facility at Ozersk (Chelyabinsk-65), Chelyabinsk region, Russia. The United States has agreed to pay for half the construction cost. Despite the urgency to provide safe storage of Russian weapon-usable fissile materials, this facility is now scheduled to be completed no sooner than February 2002, almost ten years after the project was launched.

11. Increased security and safe disposition of existing stocks of weapon-usable materials.

The DOE's lab-to-lab effort to improve the Material Protection, Material Control and Accounting (MPC&A)) at facilities that contain weapon-usable fissile materials has improved security at numerous facilities in Russia and the Newly Independent States and is worthy of continued support. The shortcomings of this program have been addressed recently by the General Accounting Office in GAO, "Nuclear Nonproliferation: Limited Progress in Improving Nuclear Material Security in Russia and the Newly Independent States," GAO/RCED/NSIAD-00-82, March 2000). This MPC&A initiative, however, will never be fully successful as long as most of the weapon-usable fissile materials are beyond the reach of this DOE initiative. It is paramount that the United States aggressively pursue other objectives identified above, otherwise the DOE initiative will never reach most of the Russian inventories that need additional security.

The effort to place under IAEA safeguards fissile material inventories that have been declared to be in excess of national security needs by Russia and the United States is moving ahead so slowly that this DOE program must be counted as a failure.

12. Verified storage and disposition of highly-enriched uranium and plutonium declared to be in excess of national security needs.

Privatization of the U.S. Enrichment Cooperation ("USEC") while appointing USEC as executive agent to manage the HEU has proven to be a mistake. The HEU deal also suffers from the U.S. government failure to aggressively pursue fissile material declarations. The United States does not know how much HEU the Russians have within plus or minus a few hundred tonnes, i.e., plus or minus about 10,000 nuclear warheads worth of HEU.

The United States program for declaring and disposing of its excess HEU is just as ludicrous as the Russian program. The U.S. has not reconciled its total HEU production with its existing inventories, even though Secretary O'Leary promised a public

reconciliation some five years ago. The United States refused to declare as excess any HEU from weapons with U-235 concentrations above 90 percent, choosing instead to save it all ostensibly for use as naval reactor fuel—a supply that will last some 80 years, or so.

The program to assist Russia in disposing of its excess plutonium is unlikely to be successful because its mission is to assist Russia in converting excess plutonium into MOX to be burned in existing reactors. Russia has no MOX fabrication facility, cannot afford one, and no country has indicated any willingness to pay for a MOX plant in Russia.

We are now told that a plan to finance a MOX fabrication facility in Russia will be presented at the upcoming G8 July summit at Okinawa, Japan. Whether the G8 can get beyond the planning stage and ante up real money remains to be seen.

The initial capacity of the proposed Russian MOX plant has been scaled back to where it can handle only about 2 or 2.5 tonnes of plutonium annually; but this is approximately the rate at which Russia is now adding to its separated plutonium stocks—by reprocessing the spent fuel discharged from its three remaining plutonium production reactors (1.5 tonnes Pu/year), processing commercial VVER-440 spent fuel (about 1 tonne Pu/year), and processing naval reactor fuel and fuel from two tritium production reactors.

The decade long project, whose initial purpose was to shut down the three remaining Russian plutonium production reactor and when that failed to convert then from weapon-grade plutonium production to reactor-grade plutonium production, has all come to naught. Even if the three production reactors and the RT-1 reprocessing plant are shut down sometime in the future it will take decades to put a significant dent in the 170 to 200 tonne inventory of separated plutonium in Russia.

Consequently, the Russian plutonium disposition effort should be refocused with a priority given to converting plutonium pits to unclassified shapes and placing this under bilateral and ultimately international safeguards.

13. Assist in downsizing Russia's nuclear weapons complex and provide alternative employment opportunities for workers in Russia's nuclear weapon complex.

The United States is involved in a variety of bilateral and international efforts that provide alternative employment opportunities for workers in Russia nuclear weapon complex. These include the Nuclear Cities Initiative (NCI), the Initiative for Proliferation Prevention (IPP), the International Science and Technology Center (ISTC), the Cooperative Threat Reduction Program (CRT) the DOE lab-to-lab program to upgrade Nuclear Material Protection, Control, and Accounting in Russia, and the highly-enriched

uranium blend-down and purchase agreement. Despite their many shortcomings these programs should be supported and improved. The status of these activities, and the need for additional funding, was recently reviewed in a conference report, Bukharin, et al., "Helping Russia Downsize its Nuclear Complex: A Focus on the Closed Nuclear Cities," Princeton University, June 2000.

A potential source of new additional revenues for several of these initiatives is the Non-Proliferation Trust, Inc. (NPT) proposal, with which I am involved. This non-government initiative has the potential to raise $15 billion in revenues, of which over $11.5 billion will be allocated to a variety of worthy projects in Russia. The revenues would be raised providing spent fuel management services in Russian for 10,000 tonnes of foreign (non-Russian and non-U.S.) spent fuel. Western companies would build and operate in Russia an interim dry cask spent fuel storage facility that would be licensed by GAN, the Russian licensing authority, and that would meet the technical licensing criteria of the Nuclear Regulatory Commission.

Under the current NPT proposal plan $2.3 billion of the revenues is allocated for the construction of a geologic repository for the foreign spent fuel in addition to Russian spent fuel and high-level radioactive waste. An additional $1.5 billion is allocated to fissile material security, $2 billion for alternative employment opportunities for workers in the Russian nuclear weapons complex, $3 billion for environmental cleanup, $0.5 billion for regional economic development, and $2.25 billion for humanitarian causes in Russia.

To be successful this initiative will have to have the support of both the U.S. and Russian governments. Key individuals within DOE are supportive of the NPT proposal, however, DOE has not offered up any public statements of support of the NPT project beyond saying that DOE could support an international spent fuel storage facility in Russia under the right circumstances. Some administration officials are examining options for exercising control over the project.

NPT anticipates that it will receive shortly a letter from the Putin Administration endorsing the basic elements of the NPT proposal. Before the project can go forward the State Duma would have to amend the Russian Law on Environmental Protection (Sec. 3, Art. 50), which prohibits the importation of radioactive waste. This could occur as early as September. Depending on how the law is amended the Duma runs the risk of sanctioning alternative waste management proposals that are not in Russia's best interest.

C. Plutonium as a Nuclear Reactor Fuel

In the late-1960s the Atomic Energy Commission was predicting that increased use of nuclear power would lead to reductions in power plant costs and scarcity and increased costs of uranium, thus making plutonium recycle and fast breeder reactors economical.

These claims have proven to be false. Nevertheless, largely on the basis of these erroneous predictions and the misguided belief that plutonium use would provide energy independence, many countries adopted the closed fuel cycle—plutonium separation and recycle—in preference to direct disposal of spent fuel. As a consequence global inventories of weapon-usable plutonium in civil stockpiles now exceed plutonium inventories in military programs, and the civil stockpiles continue to grow largely as a consequence of commercial reprocessing contracts made years ago.

Since the 1960s the price of uranium in constant dollars has actually declined. The cost of commercial fuel reprocessing and plutonium fuel fabrication have increased. Today it is abundantly clear that fast breeder reactors and plutonium recycle in thermal reactors is uneconomical and will remain so for the foreseeable future. The commercial use of plutonium in most countries is on the decline. At the Oslo-Paris (OSPAR) convention meeting in Copenhagen on June 30, 2000, twelve European countries—Denmark, Ireland, the Netherlands, Belgium, Switzerland, Sweden, Spain, Portugal, Iceland, Germany, Norway and Finland—voted to end nuclear fuel reprocessing. The United Kingdom and France abstained so as not to be legally bound by the vote. Four countries voting against reprocessing—Germany, Switzerland, Spain and Sweden—had contracts with BNFL. Germany and Switzerland have halted further commercial contracts for plutonium separation. DOE and the Russian Ministry of Atomic Energy (Minatom) are now negotiating a bilateral 20-year moratorium on commercial reprocessing of nuclear spent fuel. Given BNFL's financial status and its MOX fabrication problems, its days as a leading reprocessor of spent fuel appear to be numbered.

The concept of accelerator transmutation of waste (ATW) has been promoted as a means of reducing the long-term risks associated with geological disposal of high-level radioactive waste. A recent DOE sponsored roadmap of the ATW concept indicates that this technology will be prohibitively expensive. More importantly, no case has been made to date that: a) the potential lives saved by reducing the transuranic and other isotopes going into a geologic repository will exceed the potential lives lost resulting from the implementation of an ATW program, b) the cost of implementing an ATW program are worth the benefits, c) greater benefits cannot be achieved at less cost by selecting an alternative repository site and technology, d) the non-proliferation benefits of an ATW program are positive, and e) that an ATW program can be implemented by private industry.

Development of ATW is a waste of money; but then the U.S. Congress and DOE have a habit of appropriating and spending the taxpayers' monies to analyze the technical details of bad ideas. Let us hope history is not repeated with ATW.

So long as the global norm permits nations to separate and stockpile large inventories of weapon-useable fissile materials ostensibly for peaceful purposes, there is little hope that the nuclear weapons states will be willing to move to small nuclear weapon stockpiles.

Since plutonium recycle is uneconomical and unnecessary for energy independence or waste management, the preferred course from a nonproliferation prospective is a complete global ban on commercial use of weapon-usable fissile material.

D. Pu-238 as a source material for radioisotope thermoelectric generators (RTGs) and radioisotope heater units (RHUs).

The DOE has supplied 44 RTGs, each containing kilogram quantities of Pu-238, and 240 RHUs, each containing gram quantities of Pu-238, on 26 space missions since 1961. In 1964 one of the RTG, a SNAP-9A RTG containing just under one kilogram of Pu-238 burned up upon reentry over the Indian Ocean, widely dispersing Pu-238 as an aerosol. Given that Pu-238 is about 250 times more toxic than weapon-grade plutonium, this kind of release must not be permitted to happen again. The problem, as we all know, is that today there are no good alternatives to the use of Pu-238 fueled RTGs and the smaller RHUs for some deep space missions. With advances in packaging the risk that the Pu-238 will be accidentally dispersed into the atmosphere can be made exceedingly low. Unless and until a more benign reliable energy source can be found, it will be necessary to continue to use Pu-238 sources for some deep space missions.

E. Conclusion

We have an obligations to the international community to eliminate nuclear weapons and convert existing stocks of separated plutonium into a form that is no more attractive as a source of weapon material than spent nuclear reactor fuel as a source of plutonium for weapons. There is no economic, environmental or non-proliferation utility in separating additional plutonium from spent fuel, at least not in the foreseeable future. Pu-238 has limited utility in small quantities for deep space missions. In sum, plutonium has a long half-life, but within the orbit of Mars it has no future.