CHAPTER 5

NEW METRICS FOR DENUCLEARIZATION

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Introduction.

The legacy of Cold War nuclear weapons programs in the United States and Russia represents serious continuing threats to each country's national security. Today, the primary danger to the United States from Russia's possession of nuclear weapons is not from a deliberate attack, but from a mistaken, unauthorized, or accidental missile launch. In addition, the Russian nuclear weapons program—more so than that of the United States—represents a continuing global proliferation threat as well as a public health and environmental hazard. The proliferation threat stems from the facts that Russia (1) is still producing and separating plutonium; (2) has some 15,000 to 20,000 assembled nuclear weapons and about 1,700 metric tons of separated nuclear weapon-usable fissile materials (much of it under inadequate security); and (3) lacks alternative jobs to offer the 67,000 workers who live in ten closed nuclear cities. Russia suffers from the most severe environmental pollution of any country and lacks the funds to clean it up. A failing economy and widespread corruption compound these problems. To reduce these risks, the United States and Russia have been engaged in a variety of programs that can be loosely described as a program of "denuclearization."

In the first part of this chapter, I examine a new approach for establishing priorities and measuring progress in denuclearization and nonproliferation. The second part addresses a new method of funding a portion of the denuclearization effort.

The Denuclearization Metric.

"Denuclearize" can be defined as either removing nuclear arms **from** an area or prohibiting the presence/use of nuclear weapons/arms **within** an area. It is the first of these two definitions that will mainly concern us here. A limitation of our definition, of course, is that it does not reflect the threats represented by partially assembled nuclear warheads, stockpiles of nuclear materials, or nuclear weapon production technologies and nuclear weapon expertise.

A useful, albeit narrow, technical metric for measuring progress in denuclearization would be a curve plotted relative to two axes, displaying the cumulative number of nuclear weapons that a state could launch or use as a function of the time it would take to use them (setting aside employment policy considerations). By this metric (see Figure 1), denuclearization is the process of reducing the area under the curve and shifting the curve and the area under it to the right. This is tantamount to reducing the number of nuclear warheads, reducing warhead potential, and increasing the time to achieve "use ready" status (e.g., to render strategic weapons ready for launch), or operational status of nonstrategic weapons. One can compare various denuclearization strategies by examining how the curve shifts over time under various proposals.

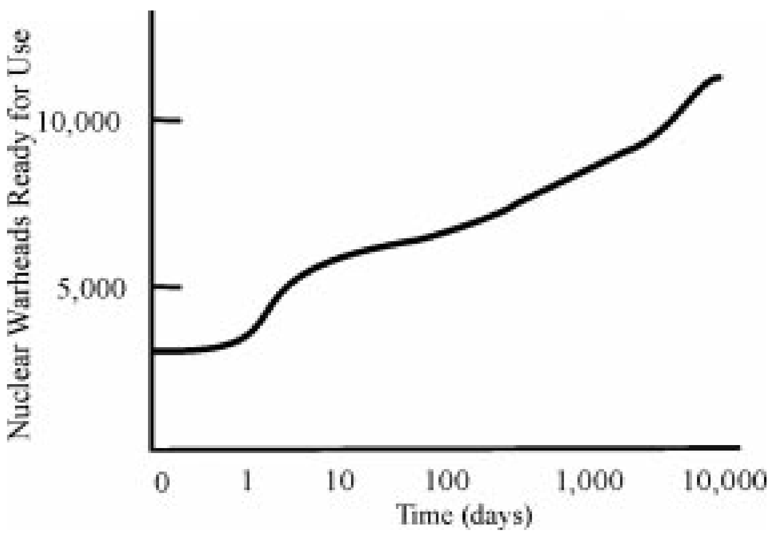

Figure 1. Notional representation of the number of nuclear warheads that can be brought to launch ready or use ready status as a function of time.

Now look at Figure 2. The same metric can be used to describe the status of nonweapon states in terms of how long it takes each state to acquire nuclear weapons and the state's capabilities to produce and field nuclear weapon arsenals. By definition, these states have no nuclear weapons at present, so the curves representing their respective weapon potential intersect the horizontal axis (representing number of days) rather than the vertical axis (representing number of nuclear warheads). But the nonproliferation objective is the same as for weapon states, that is, to shift the curves to the right. In Figure 2 the international safeguards "timely warning criterion" is met for a given country only if the time period represented by the distance from the origin to the horizontal axis intercept is sufficiently long for the international community, through diplomatic pressure and sanctions, to prevent the state from acquiring nuclear weapons should the state seek such a an option. In a non-nuclear world, all states would be represented by curves similar to those depicted in Figure 2.

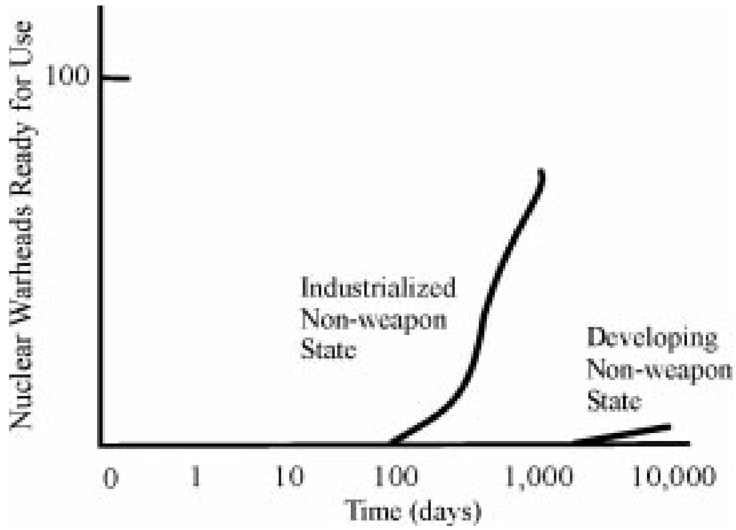

Figure 2. Notional representation of the number of nuclear warheads that can be produced and brought to launch ready or use ready status as a function of time.

To avoid having to determine and address a state's capability to fabricate nuclear warheads and delivery vehicles, the nonproliferation metric in Figure 2 can be usefully simplified by changing the vertical axis so as to portray "quantity of weapon-usable fissile material" in place of "nuclear weapons ready for use." Or an agency like the International Atomic Energy Agency (IAEA) might plot "Significant Quantities of Fissile Material," to use a different example.

Returning to Figure 1, to accurately plot such a curve one needs to know the number of warheads and the amounts of fissile materials in various categories of warheads, warhead components, and fissile materials. For example, today the United States has over 2,600 warheads on "launch ready" alert that can be launched in a matter of minutes. Within a few days the United State could bring its strategic forces to "Generated I" alert status by moving some five or so additional submarine-launched ballistic missiles (SLBMs) on station, thereby adding another 960 or so warheads to use ready status.

One can continue this exercise by including the strategic bomber force, nonstrategic bomber weapons, and hedge weapons, some of which would take progressively longer to bring to launch ready status. It would take even longer to activate inactive warheads, still longer to reassemble pits and canned subassemblies into usable warheads, and even longer still to manufacture new warheads from fissile and other materials.

Table 1 ranks various categories of warheads, warhead components, and fissile materials in terms of how long it would take to attain use ready status. As seen from the table, denuclearization is more complicated than just eliminating nuclear weapons. Denuclearization is the process of moving warheads and materials from categories high on the Table 1 list to categories lower on the list. Moreover, movements between any two categories are not of equal worth. For example, when there are numerous warheads in the higher-ranked categories, as is the case today in the United States and Russia, then progress in moving fissile materials down through the lower ranks will not substantially alter the risks associated with a state's use of nuclear weapons. In general, the "worth" of each step becomes progressively less as one moves down through the list of categories in Table 1. In order to make the area under the curve more representative of the "worth" of the weapons and weapon materials, I have selected a logarithmic scale for the horizonal axis in Figures 1 and 2, meaning that the number of days increases exponentially with each incremental move to the right.

RELATIVE EMPLOYMENT PREPARATION TIME
Launch Ready Alert Level Warheads
Warheads Added by Bringing Forces to Generated Alert Status
Other Deployed Warheads
Non-Deployed Warheads in the Active Stockpile
Inactive Stockpiled Warheads
Warheads Awaiting Disassembly
Stored Pits and Canned Subassemblies
Plutonium (Pu) and High-Enriched Uranium (HEU) in Metallic Form
Pu and HEU Oxides and Other Chemical Forms
Pu and HEU in Fresh Fuel Assemblies
Pu and HEU in Spent Fuel Assemblies
Low-Enriched and Natural Uranium
Spent Fuel in Geologic Repositories
Uranium Ore

Table 1. Warheads, Warhead Components, and Fissile Material Stocks Ranked Approximately According to the Time It Takes to Achieve Launch Ready Warhead Status.

Thus far we have discussed denuclearization in the context of reducing the risks associated with a weapons state's use of nuclear weapons, either deliberately or accidentally. We also want to reduce the risk of nonweapon states and nonstate entities acquiring nuclear weapons, for example, by diverting nuclear weapons, weapon-usable materials, or expertise from a weapon state. The proliferation risks associated with a weapon state's nuclear weapons program can be reduced by the following measures:

- Reducing the total stocks of weapon-usable nuclear materials available for diversion;

- Improving the security of existing stocks of fissile materials; and/or

- Reducing the likelihood of transfer of nuclear expertise for unauthorized purposes.

Note that reducing the total stocks of nuclear weapons and weapon-usable nuclear materials reduces both the weapon state threat and the nonweapon state threat associated with these materials. The denuclearization metric therefore has utility in measuring progress in reducing the risk of diversion. The denuclearization metric, however, is less useful for establishing priorities for measuring progress in improving security of fissile material or reducing the likelihood of transfer of nuclear expertise, except that taking steps to move the curve down and to the right does lessen the prospect of readily available warheads and materials and it potentially leads to a lessening of expertise.

U.S. Denuclearization Priorities.

The United States is pursuing several somewhat independent denuclearization and nonproliferation efforts in cooperation with Russia: (1) nuclear arms reduction negotiations—the START II/III treaty negotiation process, which the Bush administration may replace by unilateral actions; (2) the START I verification program; (3) the Cooperative Threat Reduction Program (so-called "Nunn-Lugar"), under which launch vehicles are dismantled; (4) the 500 metric tons highly-enriched uranium (HEU) purchase agreement, under which HEU from weapons is blended down into nonweapon-use fuel for power reactors; (5) the joint U.S.-Russian plutonium disposition program; and (6) various efforts to improve the security of existing stocks of nuclear weapons and fissile materials.

In broad terms, there are several shortcomings with these efforts. First, the six program elements were not developed as part of a comprehensive integrated package. The United States has neither a comprehensive nor an integrated strategy for achieving progress in denuclearization. The United States attaches high priority to efforts that have the lower worth, e.g., the plutonium disposition program, and little priority to some efforts that have a higher worth, e.g., removing warheads from launch ready status ("de-alerting"), and dismantling canned subassemblies. Moreover, the United States attaches little priority to achieving a data exchange with Russia in order to ascertain the number of nuclear warheads, warhead components, and fissile material stocks in the various categories in Table 1. The United States does not know, within plus or minus a few thousand, how many tactical nuclear warheads Russia has retained in its arsenal. Without a reliable data exchange, the United States cannot measure or verify progress in denuclearization.

Let us now turn to an analysis of some of the specific ongoing U.S.-funded denuclearization and nonproliferation initiatives in Russia.

U.S. Nonproliferation Initiatives in Russia.

Since the collapse of the Soviet Union almost a decade ago, the U.S. Government has initiated a variety of Russian-based programs with the following objectives:

- Improve the security of existing stocks of fissile materials in Russia to reduce the likelihood of theft and unauthorized use;

- Reduce the total stocks of weapon-usable nuclear materials; and,

- Provide alternative employment opportunities to nuclear, chemical, and biological weapons experts to reduce the likelihood that they would sell their expertise abroad.

In addition, the ongoing programs provide transparency with respect to nuclear weapon and other activities in Russia.

The United States has been spending about $500 million a year on the Russian safeguarding effort. The Bush administration has initiated a "comprehensive review" of these programs. I do the same here, beginning with a brief summary of the principal ongoing initiatives.

Improving the Security of Fissile Materials.

There are several ongoing efforts, the main ones being as follows:

- **Russian Fissile Material Storage Facility at Ozersk**. Provides assistance in the construction of a large storage facility at Ozersk (Chelyabinsk-65) and construction of 10,000 special fissile material containers for use in this facility. The construction of the first of two wings is almost complete, and loading of this wing is scheduled to commence in FY2002. When both wings are complete, the facility will hold the fissile materials from approximately 12,500 warheads. Construction costs of the first wing were capped by Congress at $460 million. Funded by DOD's Defense Threat Reduction Agency under the Cooperative Threat Reduction (CTR) budget (FY2001, $57.4 million);

International Materials Protection, Control, and Accounting (MPC&A). This is a program to install improved security systems at civilian nuclear sites, naval fuel and weapon sites, and nuclear weapon laboratory sites, and to consolidate nuclear materials at fewer sites. Founded by Department of Energy/National Nuclear Security Administration (FY2001, $169.7 million; FY2002, $138.8 million);

Improve Security at 12 GUMO Nuclear Weapon Storage Sites. Provides assistance to the Russian Ministry of Defense's 12th Main Directorate (12th GUMO) to improve security at nuclear weapon storage sites (other than Russian Navy sites). Funded by DOD under the CTR budget (FY2001, $89.7 million);

Improve Nuclear Weapon Transportation Security. Provides assistance to the Russian Ministry of Defense's 12th GUMO to improve nuclear weapon transportation security. Funded by DOD under the CTR budget (FY2001, $14 million); and,

Pit Conversion and Fissile Material Packaging. Provides assistance to the Russian Ministry of Defense's 12th GUMO to facilitate packaging of fissile materials from dismantled warheads for subsequent shipment to and storage at the storage facility at Ozersk now under construction. Funded by DOD under the CTR budget (FY2001, $9.3 million).

These five initiatives all deserve support. A problem, however, with respect to all of them is that the United States (and possibly Russia) does not know how many nuclear weapons and how much fissile material exist in Russia, and the United States does not know where much of it is stored. The United States has failed to make a high priority effort to secure a bilateral data exchange on weapon and fissile material inventories.

Referring back to the categories in Table 1, we see that the United States has placed relatively high priority on storage of plutonium and HEU in metallic form (i.e., at Ozersk), but there is no joint program associated with some efforts described in Table 1 that are of higher worth, e.g., accelerating disassembly of the warheads.

Reducing Stocks of Weapon-Usable Nuclear Materials.

The principal ongoing efforts here are as follows:

- **Highly-Enriched Uranium (HEU) Purchase Agreement**. A U.S.-Russian agreement whereby 500 metric tons of HEU from Russian weapons are to be blended down into low-enriched uranium (LEU) for use as power reactor fuel, and the purchase by the United States of the separative work unit (SWU), or enrichment values, of the LEU. To date, just over 100 metric tons of the 500 have been sold and delivered to the U.S. Enrichment Corporation (USEC), the government appointed executive agent for the HEU purchase agreement. DOE provides funds for implementation of transparency agreements associated with the blend-down of HEU into LEU in Russia (FY2001, $14.6 million; FY2002, $14.0 million);

- **Plutonium Disposition**. Under this program, 34 metric tons of weapon-grade plutonium are to be eliminated by both Russia and the United States by first converting it to mixed plutonium oxide and uranium oxide (MOX) fuel and then using the MOX fuel in nuclear power reactors, thereby converting it into spent reactor fuel. Funded by DOE/National Nuclear Security Administration (FY2001, $56.5 million; FY2002, $62.0 million; less use of prior years' balances, the totals are reduced to: FY2001, $41.5 million; FY2002, $20.0 million); and,

- **Plutonium Production Reactor Core Conversion**. An effort designed to assist Russia in converting the three remaining dual-purpose (plutonium and energy production) reactors to reduce or eliminate weapon-grade plutonium production. There are three options under consideration: converting the reactor cores to LEU fuel; converting them to HEU fuel; and replacement of the reactors with non-nuclear power plants. Funded by DOD's Defense Threat Reduction Agency under the CTR budget (FY2001, $32.1 million).

There are two problems with the HEU Purchase Agreement that should be rectified. First, the U.S. Government has turned this program over to what is now a private company, the U.S. Enrichment Corporation

(USEC), which serves as the Government's executive agent for implementing the program. Under this arrangement, to the detriment of the program, the profit motive of USEC has become a higher priority than the denuclearization objective of the United States. Second, the United States does not know the quantity and disposition of Russian HEU, so the worth of this effort is difficult to gauge.

The plutonium disposition program is an example of misplaced priorities. It would be far more productive for the United States to spend its diplomatic capital and taxpayer funds on converting plutonium pits into plutonium "pucks" (unclassified shapes) and putting the plutonium pucks under international safeguards, certainly more productive than trying to fund and construct a Russian MOX fuel fabrication plant. The proposed MOX plant will not even keep up with the current rate at which Russia is separating new plutonium from dual-purpose plutonium production reactors and from commercial power reactors. Moreover, Russia has so few VVER-1000 reactors, it cannot convert more than a few metric tons of plutonium into spent fuel annually, even if a MOX fabrication plant were built in Russia. Finally, a Russian MOX program will likely increase proliferation risks in the long run.

The Plutonium Production Reactor Core Conversion program has been stymied by the failure of Russia and the United States to reach agreement on what the end point of the conversion effort should be—use of LEU or HEU fuel, or replacement of the three reactors. The proposal to convert the reactor to HEU fuel is ill-conceived in that the proliferation risks associated with the HEU fresh fuel are no less than the risks associated with the separated plutonium.

Alternative Employment Opportunities for Nuclear Workers.

The principal ongoing efforts here are as follows:

- **International Science and Technology Center (ISTC).** This is an intergovernmental organization established in 1992 by agreement between the European Union, Japan, the Russian Federation, and the United States. Headquartered in Moscow, ISTC provides weapons scientists from CIS countries with opportunities for redirecting their scientific talents to peaceful science. In 1999 there were 201 projects covering 17,815 participants funded at $42.6 million, with the United States contributing $13.2 million. The participants worked an average of 63 days on the ISTC funded projects, so the participation was more like 4,800 full-time equivalents. The ISTC paid the 17,815 project participants $22.6 million in grant money, which works out to an average salary of about $4,700 per year ($20 per day).

- **Initiatives for Proliferation Prevention (or IPP, formerly called the Industrial Partnering Program).** This is a program to facilitate and promote employment and economic development opportunities for displaced nuclear weapon scientists and engineers. Efforts focus on cooperative projects involving DOE laboratories and research institutes in Russia, Ukraine, Kazakhstan, and Belarus. Every dollar the U.S. Government provides for a project is matched by industry. The federal contribution is funded by DOE/National Nuclear Security Administration (FY2001, $24.1 million; FY2002, $22.1 million);

- **Nuclear Cities Initiatives (NCI)**. This is a program of cooperation with the Russian Ministry of Atomic Energy (Minatom), commercial entities, and local and state governments to create civilian ventures in one of the ten closed nuclear cities. Funded by DOE/National Nuclear Security Administration (FY2001, $26.6 million; FY2002, $6.6 million).

While these three initiatives have not prevented senior Minatom and Russian Institute officials from providing nuclear weapon related assistance to Iran, they are nevertheless useful and cost effective. This is particularly the case with respect to the ISTC and IPP programs. The NCI initiative is too new to have established a track record, but it will likely suffer from the facts that (1) DOE and the national laboratories have very limited expertise in commerce, and therefore will have difficulty in identifying potential commercial markets; and (2) the business must be successful, particularly in Russia. All three programs, ISTC, IPP and NCI, have effective measures in place to prevent the misallocation of funds, and all provide useful transparency at institutes where funded research is conducted. Looking beyond the next few years, there are better ways to accomplish the objectives of these programs. As an alternative, the United States should consider financing a program that encourages early retirement of Russian workers.

All three ongoing programs cited above require the identification of a scientific project, or alternative employment opportunity, before the Russian participant can receive financial support. None provide an incentive for Minatom or its workers to shut down entire weapons-related facilities, e.g., a fuel reprocessing or chemical separation plant. To provide such an incentive, the United States should consider establishing a trust fund to pay for the early retirement of Russian nuclear workers. The workers at targeted facilities would take early retirement and be permitted to pursue other nonweapons employment. The trust would not be required to provide alternative employment projects as a condition for shifting from weapons work.

The ten closed cities[1] that host most of the Russian nuclear weapons program have a total population of about one million people. The total number of weapons workers in these cities in 2000 was some 60,000-67,000, a number that is projected to drop by about 50 percent over the next 5 years as Minatom downsizes its nuclear weapon work force.[2] If the 32,000 person projected work force (or projected work force reductions) were to be underwritten at the rate the ISTC paid project participants in 1999 ($4,700 per year), the total cost would be $150 million per year. Comparatively, this represents 2.8 percent of the FY2002 DOE Stockpile Stewardship Program budget.

Funding Denuclearization.

In January 2001, a DOE-appointed nonproliferation task force co-chaired by Lloyd Cutler and former Senator Howard Baker, Jr., concluded that:

> Current nonproliferation programs of the Department of Energy, the Department of Defense, and related agencies have achieved impressive results thus far, but their limited mandate and funding fall short of what is required to fully address the threat. . . . The current budget levels are inadequate and the management of the U.S. government's involvement is too diffuse.

A private initiative called the Nonproliferation Trust, Inc. (NPT) offers an alternative source of substantial funding to augment U.S. Government-funded security efforts. Since Western governments have demonstrated they are unwilling to invest the necessary resources to adequately address the security problems in Russia, NPT's goal is to step into the breach by augmenting government funds with private capital associated with nuclear spent fuel management.

The Non-Proliferation Trust is a Delaware corporation whose purpose is to foster global nuclear nonproliferation plus environmental and humanitarian initiatives. NPT proposes to raise $15 billion by taking title to 10,000 metric tons of foreign (non-U.S. and non-Russian) nuclear spent fuel and storing it in Russia. The project would require $3.45 billion to safely manage the spent fuel, an amount which could cover purchasing spent fuel storage casks, constructing and managing a dry cask storage facility, and transporting the fuel. The project would allocate more than 75 percent of the revenues—the remaining $11.55

billion—to nonproliferation, environmental, and humanitarian causes in Russia.

Environmental Cleanup	$ 3.0 billion
Fissile Material Security	1.5
Geologic Repository Siting and Construction	1.8
Spent Fuel Escrow/Repository	0.5
Alternative Jobs for Nuclear Weapon Workers	2.0
Regional Economic Support	0.5
Humanitarian (pensioners and orphans)	2.25
Total:	**$11.55 billion**

NPT currently plans to allocate the $11.55 billion as follows:

To prevent the misuse of these funds, the monies would be managed by three U.S.-based charitable trusts: the Minatom Development Trust, the Russian Environmental Trust, and the Russian Humanitarian Trust.

The NPT project is still in the conceptual stage. Much work and additional negotiations are required to develop it more fully. Moreover, the project cannot go forward unless there is an agreement for cooperation on nuclear matters between the United States and Russia.

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1. Sarov (Arzamas-16), Snezhnisk (Chelyabinsk-70), Ozersk (Chelyabinsk-65), Sversk (Tomsk-7), Zheleznogorsk (Krasnoyarsk-26), Novouralsk (Sverdlovsk-44), Zelenogorsk (Krasnoyarsk-45), Lesnoi (Sverdlovsk-45), Trekhgornyi (Zlatoust-36), Zarechnyi (Penza-19).

2. Oleg Bukharin et al., *Helping Russia Downsize Its Nuclear Complex: A Focus on the Closed Nuclear Cities*, Princeton: Princeton University Press, June 2000.