Viewpoint

Thoughts about an Integrated Strategy for Nuclear Cooperation with Russia

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The "new" Russia will soon celebrate its tenth anniversary. Gone are the initial romantic notions of a rapid transition to a free-market democracy and a civil society. Instead, the stark reality has set in that the accumulated damage of 500-plus years of repressive, autocratic rule continues to haunt all efforts to reform. Russia finds itself in a centuries-old dilemma of a love-hate relationship with the West, and it is not at all clear which path Russia will take.

The stakes are high for the rest of the world, because Russia has nuclear weapons—lots of them and big ones. With its nuclear arsenal Russia remains the only country that can threaten the very existence of the United States. The attempted coup in August 1991 and the attendant uncertainties about the control of the Soviet nuclear arsenal underscored a vital concern: how Russia manages and protects its nuclear assets will influence U.S. security and potentially threaten U.S. citizens and assets around the world. In the years that followed, the threat of "loose nukes" and the "clear and present danger" posed by Russia's large and poorly secured stock of weapons-usable materials—plutonium and highly enriched uranium (HEU)—arose as new threats whose solution require cooperation between Russia and the United States. This article describes an integrated strategy for nuclear cooperation with Russia to address the current threats.

As we look back over the decade since the collapse of the Soviet Union, the good news is that nothing really terrible happened within the Russian nuclear complex in spite of the difficult times faced by the Russian people. The early years were marked by surprising cooperation between our governments in the nuclear arena, both through unilateral actions on each side (most notably, the presidential initiatives in the fall of 1991) and through the initial implementation of the Nunn-Lugar Cooperative Threat Reduction (CTR) program.[2] In parallel, informal scientific networks between nuclear scientists in Russia and the United States were established to tackle those problems not easily handled by formal governmental diplomatic agreements.[3]

The keys to the early success of these programs were cooperation and leadership. The CTR programs managed by the U.S. Department of Defense (DOD) played a key role in the return of Soviet nuclear weapons from the

newly independent states (NIS) of Ukraine, Kazakhstan, and Belarus. They helped to eliminate much of the nuclear infrastructure in these states (e.g., rockets, silos, test site facilities, etc.). They provided technical assistance to the Russian military to protect these and other weapons in transit as Russia was relocating them to more secure sites. Later on, the CTR programs helped Russia protect its nuclear weapons storage sites and begin construction of a modern, well-safeguarded fissile materials storage facility. In cooperation with the Republic of Kazakhstan, the U.S. government helped remove almost 600 kilograms (kg) of HEU from an unsecured site to the West.[4] The U.S. Department of Energy (DOE) nuclear weapons laboratories initiated a lab-to-lab scientific collaboration with the Russian nuclear weapons institutes, followed by cooperative efforts on nuclear materials protection, control, and accounting (MPC&A) with their Russian counterparts.[5] Together these efforts helped to reduce but not eliminate the immediate risks. Moreover, these cooperative programs based on mutual respect and objectives built up a bank account of trust and good will between the Russian and U.S. nuclear complexes.

The bad news is that the problems in the Russian nuclear complex were much greater and more pervasive than either Russians or Americans realized ten years ago. For example, the Russian nuclear complex in 1992 was vastly oversized and overstaffed for post-Cold War defense requirements and had been in difficult economic straits for years. Yet, unlike in the United States, dramatic downsizing of the Russian complex was believed too risky by its government. Such downsizing was painful in the United States, but was ameliorated by significant increases in federal environmental budgets at DOE nuclear sites and by a healthy U.S. economy. In Russia, on the other hand, the most sensitive nuclear operations were conducted in closed cities that depended entirely on defense orders. These cities were embedded in a country with a bankrupt federal government whose governing institutions were collapsing. Laying off workers in the closed cities risked serious social unrest. Opening up the cities for business development posed a major proliferation risk. Consequently, the Russian government chose to proceed with a slow but deliberate conversion-in-place program.[6] Such an effort would have been difficult under conditions of a healthy economy and was extraordinarily difficult for these isolated cities in a chaotic national economy. Hence, although this deliberately cautious approach slowed the much-needed downsizing of the nuclear complex, it helped protect both nuclear materials and nuclear secrets. Nuclear facilities in open cities generally experienced a more abrupt and less secure transition, as did the Russian Navy. Several confirmed thefts of nuclear materials in the early 1990s, albeit of small quantities, highlighted the vulnerability of the Russian nuclear complex.[7]

At the same time, U.S. advisors and government policies did not effectively help Russia deal with the root causes of the nuclear security problems, namely radical changes of its political, economic, and social systems. The rise of the Russian oligarchs in the new capitalistic economy and the flight of huge sums of capital out of Russia further impoverished the Russian people and increased resentment of the West. The war in Chechnya heightened internal insecurity and drained money from the already strapped federal budget. Anti-Western sentiments were further fueled by U.S.-led efforts to expand NATO and to bomb Yugoslavia. These difficulties increased tensions between the two governments and began to weigh heavily on cooperative nuclear programs. A lack of a clear, coherent and sustained U.S. strategy to deal with the new nuclear dangers in Russia and the other newly independent states of the former Soviet Union resulted in a patchwork quilt of nuclear programs—often lacking coordination not only with Russia, but also within the U.S. interagency community. Furthermore, some of the programs promoted by the United States did not adequately incorporate Russian strategic objectives, forcing the Russian government to choose between following its national interest and receiving much-needed financial assistance.

Without clear strategic objectives and effective interagency coordination, program planning and execution by U.S. federal agencies did not meet the demands of sensitive cooperative programs. The technical foundations and concerns of some of the cooperative programs were often not well represented on the U.S. side. Many of the programs were managed in a grant or foreign aid mode rather than cooperatively with shared objectives, joint planning, and mutual respect. Consequently, such programs did not meet their goals and were left vulnerable to criticism from audits by the U.S. General Accounting Office (GAO).[8] Although Russian officials needed financial assistance, they bristled at the terms and conditions dictated by their U.S. government counterparts. Rather than striving to meet strategic objectives, U.S. program managers were guided by the most recent

stinging GAO appraisal. Many of the programs suffered a serious loss of partnership and progress.[9] Consequently, the bank account of trust and good will built up early in the decade was drawn down steadily to near bankruptcy by the end of the decade. Concurrently, government bureaucrats on both sides began to disempower the informal networks constructed early in the program. These actions began on the U.S. side but were quickly matched by the Russian side, where old-style Soviet tactics by Russian bureaucrats began to slow everything from access to closed cities to progress on cooperative programs.

In Russia, the government and the nuclear complex experienced severe financial distress through most of the 1990s and suffered an economic meltdown in August 1998. Political turmoil, the rise of the oligarchs, organized crime, widespread corruption, and domestic terrorism brought about a condition that lent public support to the return of "law and order." These issues coincided with, and may have been partially responsible for, the rise of Vladimir Putin. Consequently, the nuclear defense sector experienced a significant reversal of the remarkable openness we found in the early 1990s. The rise in the presence and power of the Russian security services was felt by all nuclear installations. Concurrently, the partial recovery of the Russian economy based mostly on the global rise of energy prices and the August 1998 devaluation of the ruble changed the economic situation in the nuclear complex for the better, giving Russia greater independence from American financial support. Recognizing the importance of nuclear weapons to its defense, Russia made a conscious effort to improve the conditions of its nuclear installations. All of these factors must now be taken into account as the United States takes stock of its nuclear cooperation with Russia.

As we look back over the past decade much has been done to help Russia deal with the clear and present danger resulting from the turmoil in its nuclear complex following the breakup of the Soviet Union. Fortunately, nothing drastic happened in spite of the difficult transition, but the United States lost a promising opportunity to help shape the future direction of Russia's nuclear enterprise and build a more secure future for both nations. Today, the window of opportunity appears to be closing, both because Russia does not need our money as desperately and because the security services have begun to close up the complex. To make progress now, the spirit of trust and partnership must be renewed, and a common set of objectives must be developed to meet the national security interests of both nations.

STRATEGIC FRAMEWORK FOR NUCLEAR COOPERATION

The focus of this article is on cooperative nuclear programs designed to reduce the risk posed by the breakup of the Soviet Union and the resulting struggle for democracy in the NIS. This article does not address strategic issues such as the risk of nuclear war or global stability. Therefore, issues of force structure, arms reduction, and ballistic missile defense are touched only lightly, although it is clear that these policy issues will provide the guidelines for nuclear cooperation. Nuclear cooperation must be couched in a framework of what kind of Russia the United States expects or wants to see emerge. The current situation has been described by many as "neither ally nor adversary" or "neither friend nor foe." Unfortunately, today many signs point to the likelihood of Russia as a reemerging adversary. On the other hand, it may be possible and desirable to have Russia develop into a true democracy, perhaps even a partner or ally. Today, the roots of democracy in Russia are very shallow and the best one can imagine in the future is Russia as an independent-minded ally in the mold of France.[10] Russia will choose its own path, as it always has in the past, but I believe that the actions the United States takes today will influence Russia's choice. I will frame my discussions in terms of three potential future relationships, as shown in Table 1 below.

How the relationship actually develops necessarily depends not only on the interests and actions of each country, but also by events beyond the control of either. The relationship may start out in one direction and then change course because of unexpected turns of events. Furthermore, today's "status quo" is an uneasy one at best and will likely require significant diplomacy by the United States to maintain. Some Western observers believe cooperation will not be required because Russia is destined to fade into strategic irrelevance.[11] I believe instead that Russia will remain highly relevant even if only for its nuclear arsenal. Moreover, if Russia slips deeper into chaos, it may use its frightening array of nuclear tools to play the part of a "spoiler" and disrupt what some envision as another American century.

The strategies for nuclear cooperation with Russia developed in this article are based on a hierarchy of the principal risks posed by the Russian nuclear complex,

Table 1: Potential Relationships Between the United States and Russia

Independent-minded ally France model
• Stability with cooperative security • Many common interests, few opposing security interests
Not friend, not foe status quo
• Stability with cooperative threat reduction • Complex mixture of common and opposing interests
Re-emerging adversary
• Deterrence • Few common interests, many serious opposing security interests

rather than starting with a review of existing joint programs. These risks are to a large extent shaped by difficulties in Russia's post-Cold War political, military, and economic transition. In the absence of a comprehensive, integrated U.S. government strategy, I present a hierarchy of risks for the purpose of discussion. I will then provide a summary of key observations in each of the areas of risk based on my interactions with people in the Russian nuclear complex over the past decade, followed by possible steps for nuclear cooperation for each of the relationship scenarios. [12]

A HIERARCHY OF RISKS

The Soviet Union developed an enormous nuclear complex at the expense of immense human and financial sacrifice. Over 50 years, the Soviet and Russian governments built many tens of thousand nuclear weapons, most with many times the destructive power of the bombs that devastated Hiroshima and Nagasaki. It is estimated that approximately twenty thousand warheads (strategic, tactical, or reserves) still exist in Russia today at dozens of deployment locations with over 100 storage bunkers and at over 60 weapons storage sites. The Soviet Union created huge amounts of weapons-usable materials: more than 1000 metric tons (MT) of HEU and between 125 and 200 MT of weapons-grade plutonium (the actual amounts are still kept secret). These materials are scattered at more than 50 sites in several hundred buildings under the control of several agencies and many institutions. It built a large network of huge nuclear production facilities: uranium enrichment at Sverdlovsk-44, Krasnoyarsk-45, Tomsk-7, and Angarsk; plutonium production at Chelyabinsk-65 (Mayak), Tomsk-7, and Krasnoyarsk-26; and serial production of weapons (assembly and disassembly) at Avangard (Sarov), Sverdlovsk-45, Penza-19, and Zlatoust-36. The complex also contained numerous nonnuclear weapons component plants.[13]

The Soviet Union also developed an extensive network of intellectual assets: three nuclear weapons laboratories (VNIIEF/Arzamas-16 in Sarov, VNIITF/Chelyabinsk-70 in Snezhinsk, and VNIIA in Moscow); dozens of specialized defense institutes throughout the Soviet Union; and several dedicated universities. There were two very large nuclear test sites, Semipalatinsk (now in the independent country of Kazakhstan) and Novaya Zemlya (an island above the Artic Circle). In addition, Russia conducted over 120 peaceful nuclear explosions scattered throughout the territories of the Soviet Union. The Ministry of Medium Machine Building, the predecessor agency to the Russian Ministry of Atomic Energy (Minatom), oversaw an enormous infrastructure that was capable of supplying everything the "closed cities" of its complex required, from city administration to heavy construction. Including civilian research and nuclear power activities, the complex employed nearly one million people. It was sometimes called a "state within a state."

Ten years ago, the nuclear weapons, materials, and know-how in this enormous complex posed an immediate threat to the rest of the world because of the imminent chaos that was to result from the breakup of the

Soviet Union. Today, I see the following hierarchy of risks, listed in order of decreasing concern and priority:

- *Avoiding a nuclear exchange* remains the highest priority, because it threatens the very existence of the United States. Although the probability of a Russian nuclear launch aimed at the United States is very low, it must be avoided at any cost.
- *Theft or diversion of nuclear weapons and nuclear materials* by criminals, terrorists, subnational groups, or states of concern represent an immediate and major threat to U.S. territory and its citizens or assets overseas.
- *Aggressive nuclear exports* by Russia of both technology and know-how represent a serious proliferation threat.
- *Leakage of nuclear weapons know-how* from the highly sophisticated Russian nuclear complex poses great risk if that knowledge gets in the wrong hands.
- *Huge amounts of weapons-usable material and the size of the Russian nuclear weapons complex* pose a long-term threat to a more stable security regime.
- *Nuclear accidents or environmental disasters* in Russia will upset world economic stability and undermine public support for nuclear power.

AVOIDING A NUCLEAR EXCHANGE

Although the breakup of the Soviet Union has dramatically reduced the probability of a nuclear exchange, we must remain ever vigilant against the possibility of accidental or unauthorized launches. In the longer term, it will be important to develop a new strategy for strategic stability. The end of the Cold War and the U.S. move toward a national missile defense clearly challenge the traditional strategies. A new strategy for strategic stability will evolve slowly and only after the role of traditional arms control, nuclear force structure balance, second-rank nuclear powers, and proliferation issues are reexamined.[14]

Observations

The cooperative and reciprocal measures taken to date by the United States and Russia to avoid accidental or unauthorized launches are not sufficient to guard against a potential nuclear catastrophe. The deterioration in Russian military infrastructure and the abysmal economic conditions of its military servicemen have exacerbated the risk dramatically. The current national missile defense (NMD) controversy threatens all other forms of military and nuclear cooperation. A genuinely hostile Russian reaction may be avoided as long as the United States engages the Russians in substantive discussions and negotiations. I believe that the Russians would like to find an acceptable accommodation, because they can ill afford another technological race. In fact, the dire state of the economy requires substantial downsizing of the Russian strategic arsenal.

In the area of direct nuclear cooperation, the CTR program continues to be in the best interest of the United States. It made impressive progress returning nuclear weapons to Russia proper and in helping to destroy missile delivery and nuclear testing infrastructures. My observations and recommendations will focus primarily on nuclear weapons stewardship and related infrastructure.[15] The Russians know as much about nuclear weapons design and production as does the United States. Their scientists and engineers are superb and their nuclear facilities have excellent capabilities—unlike so many of the experimental facilities in the former Soviet Union. Their theoreticians and mathematicians are world class. They make up for lack of up-to-date computer hardware by creative software design. The Soviet nuclear stockpile relied at least as much on nuclear testing as that of the United States, perhaps more because Soviet scientists were not trusted as much by their government, giving testing extra gravity. The Russian nuclear designers and engineers quite freely express concern about keeping their nuclear weapons safe and reliable without nuclear testing.

Russia has historically chosen a different approach to stewardship, choosing to remanufacture weapons every ten years instead of attempting to extend service lifetimes, as we have done in the United States. Russia is currently reexamining this approach because of concern about the long-term viability of portions of the nuclear weapons production complex. Russian officials freely state that they have "plenty of tritium and plutonium," but also acknowledge that they have shortcomings in the rest of their complex, such as the inability to fabricate beryllium.[16] Attention to nuclear warhead safety in the Russian complex was very good. Their nuclear facilities, however, would not pass current U.S. safety and environmental standards. The military played a greater role in the "cradle-to-grave" cycle of nuclear weapons, compared to the United States. Russian leadership has frequently stated that nuclear weapons are more important today to Russia's security than they were even dur-

ing the Cold War. This belief stems from the demise of Russian conventional military capabilities and instability along Russia's long and troublesome southern border. In addition, NATO expansion and the bombing of Yugoslavia have also made the Russian government rethink its nuclear strategy. Nevertheless, the Russian strategic forces are in rapid decline because of economic constraints. However, I am convinced that the Russian government will do whatever it takes to keep at least a minimal nuclear stockpile reliable.

Potential cooperation

Nuclear cooperation with Russia to prevent inadvertent launches and improve the safety and security of the Russian nuclear arsenal must be integrated into the U.S. political and military framework. The issues of strategic arms reduction, national missile defense, lengthening the nuclear fuse, and tactical arms reduction will be the cornerstones of such a framework. As an illustrative example, let us view these overarching military issues within the framework of the relationships discussed above. For example, deeper arms reductions make sense in any of the three scenarios, although the levels of such reductions would necessarily differ. On the other hand, national missile defense options could vary from cooperative missile defense for the ally scenario, to a compromise on NMD for the status quo scenario, to a unilateral U.S. deployment for the reemerging adversary scenario. The principal motivation for direct nuclear cooperation with Russia covered in this article should be to avoid inadvertent launches, to keep our own stockpile safe, reliable, and effective, and to keep the Russian stockpile safe and secure.

Military cooperation to avoid inadvertent use. To avoid accidental or unauthorized nuclear launches, it is imperative that Russia and the United States enhance military-to-military exchanges, which have waned in the past few years. Additional measure must be taken to more effectively de-alert strategic weapons on both sides and significantly lengthen the time required to launch. Both military and nuclear specialists should be tasked to develop mechanisms to strengthen weaknesses in Russia's early warning systems, weapons security, and use control. These measures should be encouraged in all three relationship scenarios, although it is unlikely that much cooperation will occur if the relationship becomes adversarial. A starting point would be for both sides to consider unilaterally deactivating the weapons they would have eliminated under the START II treaty.

Weapons safety and security exchange. Limited exchanges of unclassified technical information have occurred between Russian and U.S. nuclear weapons scientists and engineers since the initial agreement between Minatom and DOE in 1996.[17] In the ally scenario, this cooperation should be expanded, and the possibility of limited exchanges of classified information should be considered, because the United States benefits if the safety and security of Russian nuclear weapons are improved. The United States should also consider exchanging unclassified data on key weapons issues such as tactical and reserve weapons. In the status quo scenario, it would still be beneficial to reinvigorate this collaboration but sharpen the focus of current activities. In the adversary case, a limited exchange is still advisable, but unlikely.

Cooperation on nuclear accident and emergency response. To date, only limited discussions and cooperation have taken place in these areas. In the ally scenario, close cooperation is advised for both prevention and response. A Joint Nuclear Emergency and Accident Response Center could be established, including joint exercises. It would be very effective to have both U.S. and Russian specialists respond to an international terrorist threat or incident. Instead of the response team covering less than half of the potential weapons designs, it could cover almost all of them. Without question, the U.S.-Russian differences of the moment would be quickly set aside if either country were faced with a credible terrorist nuclear weapon threat. In the status quo scenario, current discussion should be deepened and some limited joint work explored. Limited or no cooperation will be possible in the adversary scenario.

Stockpile stewardship technical cooperation. Both countries are living with a nuclear test ban regardless of the current status of the Comprehensive Test Ban Treaty (CTBT). Scientists on both sides recognize the difficulty of annual certification of an aging stockpile in the absence of nuclear testing. There are many areas of fruitful unclassified technical cooperation such as the aging of plutonium, computational materials modeling, response of materials to dynamic and shock loading conditions, and a variety of experimental techniques using lasers, pulsed power, or accelerators. Such collaborations were envisioned during bilateral discussions at the time

of the signing of the CTBT, but very few topics were pursued because of congressional concerns that the Russians might benefit militarily. I believe that the United States has benefited significantly from the limited exchanges to date. Such collaboration will help the United States keep its stockpile safe and reliable and should be increased significantly under the ally scenario. It is also advisable to seek scientific collaboration with the technical institutes of the Russian Ministry of Defense. In the status quo scenario, a very limited and focused set of interactions should be pursued, whereas only international scientific cooperation is advisable in the adversary case.

Joint test site collaboration. The agreement between Presidents Reagan and Gorbachev to conduct "Joint Verification Experiments" in 1988, designed to increase each side's confidence that the other side was complying with the provisions of the Threshold Test Ban Treaty (signed in 1974 but not ratified until 1990), was a landmark in nuclear cooperation. It demonstrated that at least in the glasnost phase of the Cold War, each country was willing to risk the intrusive presence of the other at its nuclear test site. For the ally scenario, I can envision significant technical cooperation at test sites, especially to develop verification methodologies and test site transparency measures for compliance with the CTBT. We may also find it advisable to conduct joint subcritical experiments at each other's test sites to study the fundamental behavior of materials under dynamic conditions. In this area, limited classified information exchanges may enhance the security of both nations. Classified information exchanges are advisable only in the ally scenario and would require a new government-to-government agreement. In the status quo and adversary scenarios, only limited information exchanges would still be advisable to encourage test site transparency.

Clearly, the types of nuclear cooperation discussed here depend strongly on the envisioned relationship scenario. It would require bold vision and action to pursue some of these initiatives, even if the overall political climate proved itself to be friendly. Such cooperation, however, would enhance U.S. national security. The technical interactions established to date between the U.S. nuclear weapons laboratories and a large fraction of the Russian nuclear weapons complex have provided the United States with an effective window on the Russian complex and its nuclear weapons program. The United States has been able to clear up many misconceptions about the Russian program, and vice-versa. By promoting continued interactions, the United States will develop a much better "early warning" system to detect any major changes in the Russian program that may affect U.S. interests.

PREVENTING THEFT OR DIVERSION OF NUCLEAR WEAPONS AND MATERIALS

The risk with the most serious consequences is the theft of an assembled nuclear weapon. This concern was greatest during the chaotic period immediately following the breakup of the Soviet Union. The CTR program sponsored a variety of projects to help Russia protect its weapons, especially during transport. Nuclear weapons were consolidated at a smaller number of sites, and the military units responsible for them, although economically stressed, have maintained remarkable discipline. A recent study recommended continued high CTR program priority for these efforts, which are now focused on upgrading security at weapons storage sites.[18] I believe the greatest overall risk is the potential theft or diversion of nuclear materials, because these materials are more accessible than weapons and their theft would have extremely serious consequences. These materials exist in many places in every imaginable form from pristine metal to scrap to waste. The difficulty of obtaining weapons-usable materials is one of the strongest impediments for the acquisition of nuclear weapons by states, subnational groups, or terrorists. Fortunately, both the enrichment of uranium to weapons grade and the production of plutonium in nuclear reactors are expensive endeavors with large signatures. Unfortunately, the collapse of the Soviet Union makes theft or diversion of such materials from its facilities or those in other countries once controlled by the Soviet Union a more likely and worrisome alternative.[19]

Observations

The Soviet Union had an admirable record of safeguarding its weapons-usable materials from theft or diversion. It relied on strict personnel and physical security along with all of the other protections of a centrally controlled police state. Even during my first visit to the Russian nuclear facilities in 1992, it was obvious that they were ill equipped to deal with the changes resulting from the breakup of the Soviet Union and loss of central control. My Russian scientific colleagues did not recognize the "insider threat" as a serious danger. The

Western system of defense in depth, in which modern technology complements physical and personnel security measures, was not in use. Thanks to two years of building confidence through scientific collaboration, we were able to initiate a joint lab-to-lab program of MPC&A funded by the U.S. government through the DOE. The lab-to-lab partnership mechanism was essential to deal with the enormous sensitivity Russians associated with all of their nuclear facilities, and this made it possible to break the stalemate that had slowed government-to-government efforts in this area.[20]

Initial MPC&A cooperation yielded substantial improvements in the protection of nuclear materials in Russia and several of the NIS. However, as the program grew, the United States lost sight of the fact that these are Russian nuclear materials in the Russian nuclear complex. As the U.S. approach changed from a cooperative approach to a more confrontational, bureaucratic approach, the Russian side began to resist what it considered excessive U.S. intrusiveness into its defense facilities. In my view, this development was the central factor that caused progress to slow significantly. On the civilian side, the United States also turned to a more heavy-handed and bureaucratic way of doing business, which again slowed the initial, relatively aggressive, rate of progress. Furthermore, Russian civilian facilities were very slow to adopt a modern safeguards culture. The Russian naval programs continue to make progress, however, because the United States is taking a more cooperative approach with a technically strong program team, and the Russian Navy has demonstrated outstanding leadership committed to improved safeguards.[21]

Today, much remains to be done to bring Russian and other NIS nuclear materials safeguards to acceptable world standards.[22] The remaining work will be very difficult because greater cooperation and trust are required to extend the program to the more sensitive facilities with large amounts of fissile materials. Also, U.S. demands for strict accountability regarding the expenditure of U.S. funds naturally conflict with strict Russian secrecy requirements.[23] Nevertheless, Russia is still not in a position to go it alone. Western technical help and financial assistance are still required. Although many Russian officials are now convinced that a modern safeguards system is imperative for all Russian nuclear programs, many still cling to the old culture, which is historically willing to accept greater vulnerability and to take greater risks. Moreover, while nuclear weapons were returned to Russia from the other NIS, significant quantities of nuclear materials were not. Thus there was a major effort to bring 600 kg of weapons grade uranium left behind in Kazakhstan to the United States, where it was blended with natural uranium to make it unusable for nuclear weapons. Efforts were also made by the United States to begin to secure tons of weapons-grade plutonium contained in the spent fuel of the BN-350 reactor in Aktau, Kazakhstan. However, the Aktau materials need additional safeguarding or complete removal from Kazakhstan. In addition, there remain weapons-useable materials in other locations, both in Kazakhstan and other NIS.

Another aspect of nuclear materials protection that has received little attention by both the U.S. and Russian governments is the protection of nuclear materials that pose a terrorist threat through dispersal rather than detonation. Such materials may be quantities of weapons-usable materials too small to make a bomb or radioactive isotopes that are not fissionable but nevertheless very dangerous. Although this threat is often assessed as "too difficult" to deal with, awareness of the risks associated with the possible terrorist use of radioactive dispersal devices (RDDs) is increasing.[24] What makes this problem so difficult is the widespread availability and poor protection of such materials, which include nuclear waste streams, industrial radiation sources, and spent reactor fuels. Although direct deaths caused by terrorist use of an RDD may be small to moderate, the collateral damage and the psychological impact would be enormous. In fact, such an attack could undermine the stability of democratic institutions and governments.

Potential cooperation

Crash effort to secure the most vulnerable nuclear materials. The loss of trust and spirit of partnership has dramatically limited progress in protecting vulnerable nuclear materials in Russia's nuclear complex. Now that Russia and some of the other NIS have a better idea of the potential vulnerabilities in the nuclear complex, it is time to engage them in a comprehensive reassessment of what facilities represent the most urgent threat. For example, often overlooked are research reactors that use enriched uranium fuel in parts of Russia and other NIS, such as Uzbekistan, Belarus, and Ukraine. These should be shut down, possibly in exchange for other research facilities that do not pose a proliferation threat.[25] Much progress has been made in the naval sector and in

improved protection during nuclear materials transportation. The joint reassessment should address what remains to be done to increase the security of the most vulnerable nuclear materials by greater protection or consolidation. These efforts should be initiated under all three relationship scenarios, although they may not be possible for the adversary case.

Improve nuclear materials protection and remove weapons-usable nuclear materials in Kazakhstan. As suggested above, the nuclear materials risks in the NIS outside of Russia are particularly great in Kazakhstan because of the quantity of material involved and its location in the troubled Central Asia region. The Republic of Kazakhstan inherited from the Soviet Union one commercial breeder reactor and four research reactors,[26] all of which use fuel posing a significant proliferation risk. The DOE MPC&A program has helped to improve the short-term security of these materials against theft by subnational groups. However, the long-term risks of diversion by a future Kazakhstani government remain high, especially for the several metric tons of plutonium in the BN-350 reactor fuel at Aktau. Current negotiations between the United States and Kazakhstan on the ultimate disposition of this material have stalled. The Russians should be brought back into the negotiations with the goal of removing all weapons-usable material from Kazakhstan, including anything left at the former Soviet nuclear test site at Semipalatinsk that may pose a proliferation risk. These problems are sufficiently important to be resolved in all three scenarios, with a strong Russian role for the ally scenario and, if necessary, without Russia in the adversary case.

Refocus MPC&A at military sites, including the weapons assembly and disassembly facilities. The bulk of the nuclear materials in Russia are still not protected by a modern safeguards system, in large part owing to the dispute between the two governments over U.S. access to sensitive Russian defense facilities. To resolve this deadlock, Russia and the United States should charge their technical specialists to revisit an approach developed several years ago that incorporated both Russian security and secrecy requirements and U.S. demands for strict accountability. With two of the four Russian serial production plants scheduled for closeout of weapons work within the next three years, the United States has a great opportunity to help Russia meet this timetable while protecting the transfer of materials and improving security at the remaining two sites. Decreasing the number of defense sites, consolidating materials at the remaining sites, and working closely with U.S. technical specialists in developing the initial programs should allow the Russian government to build an effective self-sustaining safeguards system at the remaining facilities. Aggressive actions are advisable for both the ally and status quo scenarios, whereas the adversary scenario will clearly not allow collaboration on such sensitive facilities.

Accelerate MPC&A with the Russian Navy. As mentioned above, Russian fresh naval fuel represented a clear vulnerability in the early 1990s. Progress continues to be made through cooperative MPC&A efforts. The Russian Navy, the Russian nuclear icebreaker fleet, and appropriate nuclear institutes should be charged with developing innovative approaches to accelerating the timetable to secure fresh naval fuels on a sustainable basis. Likewise, it may be time to deal with old spent naval reactor fuel (both fuel on land and that dumped into the arctic seas) that has decayed to sufficiently reduced levels of radioactivity to pose a proliferation threat now or in the near future. Cooperation in this area is advisable in the ally and status quo scenarios, but difficult to justify in the adversary case. However, if the Russian Navy would continue to cooperate—even in the adversary scenario—then continuing the program to secure high-risk materials is advisable.

Reengineer MPC&A at Russian civilian nuclear sites. It is time for both sides to take stock of accomplishments and remaining challenges and redesign the program accordingly. The objective should be to have Russia take responsibility for enhanced safeguards systems, including developing indigenous regulatory mechanisms within the Russian government. The current regulatory reform is proceeding at a very leisurely pace, because there is little U.S. urgency and much Russian foot-dragging. All of these efforts require closer collaboration with the International Atomic Energy Agency (IAEA) safeguards program, perhaps considering the stricter IAEA physical protection standards because of additional concerns about Russian facilities. These actions are advisable under all three scenarios.

Downsize civilian and military nuclear complexes. The number of facilities that require nuclear safeguards in Russia and the NIS may be nearly one hundred. One of the best ways for Russia to build a sustainable MPC&A program is to consolidate its nuclear materials (both storage facilities and those that process or handle

materials) in fewer, but better protected facilities. Such consolidation faces not only serious political opposition, it also creates great difficulties because of the displacement of thousands of nuclear workers, and it requires significant capital for safeguards system improvements and consolidated storage space. Russia and the NIS need Western technical and financial help for these efforts. A second wing of the Mayak fissile materials storage facility may be able to play an important role not only for plutonium from stockpile returns, but also from site consolidation. Such cooperation is advisable for all three scenarios, but unlikely in the adversary case.

Explore and remediate non-conventional proliferation threats. In addition to concerns over "high-grade" nuclear materials, we must also examine less likely, but still troublesome, low-grade sources of nuclear materials such as production residues, nuclear wastes, nuclear testing residues, or nuclear systems intentionally or accidentally dumped at sea. We should engage Russian technical specialists in evaluating the potential proliferation threats posed by such low-grade sources over a time horizon of at least 50 years. Such analyses will require an intimate knowledge of all nuclear facilities and nuclear practices going back to the beginning of the Soviet nuclear era. Such analyses are best done by appropriate Russian nuclear specialists. The likelihood of conducting such analyses and their pace can be greatly accelerated by financial assistance from the West. If these analyses show that reclaiming nuclear materials from such sources is easier than producing new materials through enrichment or reactor production, then remediation should be examined and pursued. In addition, such low-grade weapons usable materials and other nuclear isotopes pose a significant threat for radioactive dispersal devices by terrorists, sub-national groups, or rogue countries.[27] Cooperation on non-conventional proliferation threats and other nuclear materials is advisable in all three scenarios, but is unlikely in the adversary case.[28]

Enhance "second-line of defense" border control programs. In addition to protecting nuclear materials at the source, it is prudent to strengthen the second line of defense against the theft or diversion of nuclear materials. One of the most obvious is to strengthen protection against the shipment of nuclear materials across Russian borders. To date, important improvements have been made through cooperative efforts at some Russian and other NIS border posts and airports. We should engage the Russian technical, border, and law enforcement specialists in developing an accelerated program for Russia and engage the other NIS to do the same. Although protecting borders in countries as large as Russia is very difficult,[29] it still provides some measure of protection and deterrence against nuclear smuggling. Such cooperation, at least on a technical basis, is advised for all three scenarios.

Cooperation to prevent the theft and diversion of nuclear materials in all of the areas discussed above is in the national interest of the United States, regardless of how the strategic relationship between our countries develops. Hence, the proposed collaboration is almost the same for the three scenarios examined here. The principal hurdle is Russia's willingness to cooperate, now that little trust remains between our countries. We must also recognize that regardless of how much new technology is brought to the table, these goals will not be fully accomplished until Russia more effectively addresses the problem of its beleaguered custodians and undergoes a major consolidation of its vast complex of nuclear facilities. Moreover, the Russian government must ensure greater accountability from the leadership of its nuclear facilities to provide effective safeguards systems.

PREVENT AGGRESSIVE NUCLEAR EXPORTS

Today, the export of nuclear power and nuclear fuel cycle technologies by Russia poses a serious proliferation risk for the United States and the world. Ironically, during the Soviet era this concern was almost nonexistent. Now, however, it is of high priority because of Russia's aggressive marketing of nuclear power exports around the world, especially the recent agreements with Iran and India. Russia's current and planned nuclear collaboration with Iran is jeopardizing most of the cooperative activities with the United States.

Observations

Minatom, with the apparent full support of the Russian government, has been a staunch proponent of increased nuclear power to meet its own and the world's energy needs: it views nuclear power as the answer. The Clinton administration, especially in its early years, viewed nuclear power as the problem. Russia views plutonium as a resource for a future of fast reactors providing limitless, clean energy for the world. The United States has viewed plutonium as an economic liability and

a proliferation threat. These disparate views have seriously hampered all cooperative efforts in civilian nuclear power, including views on export policies and practices. Russian officials have viewed some U.S. cooperative nuclear programs or proposals with great suspicion and mistrust, as many believe the United States wants to phase out nuclear power worldwide.[30]

Export controls are a matter of risk vs. benefit, often viewed differently by different nations. The United States views Iran as a state that promotes international terrorism, whereas Russia views it as a strategic ally. The United States sees only risk and no benefit in exporting nuclear power and other nuclear technologies to Iran. Russia, on the other hand, sees a manageable risk and significant benefit. The most obvious is the economic benefit of finishing the Bushehr reactor, which is on the order of a billion dollars. Also, nuclear technologies are one of the few high-tech Russian exports. Moreover, Russia views the jobs created within its nuclear complex by exports to Iran as a crucial element in avoiding social upheaval in its nuclear institutes and nuclear cities. My Russian colleagues freely admit that it would be folly to help supply neighbors on their unstable southern border with nuclear weapons. However, Russia, they say, has a different view of vulnerability than the United States, because it has lived with great vulnerability to its territories from the beginning of the Russian state, whereas the United States strives for territorial invulnerability.

The Russian government fiercely defends its cooperation with Iran, claiming to take the high road of promoting "Atoms for Peace." It brands U.S. commitments to help North Korea build nuclear reactors while trying to block similar efforts by Russia in Iran as hypocritical, refusing to recognize that the United States used its sale of light water reactors to slow proliferation in a country with an advanced military nuclear program, while Russian sales of the same technology will advance previously negligible nuclear skills in Iran. What the Russians do not discuss in the open is how their government or individual institutes have explored smaller, much more troublesome cooperative projects with Iran that cover much of the rest of the nuclear fuel cycle. Instead of resolution, we have witnessed a cycle of attack and counterattack by Russia and the United States. The recent agreements between Russia and India for increased nuclear power cooperation have only made matters worse. Russia's decision in 2000 to supply the Tapur reactor in India with nuclear fuel appears in flagrant violation of its Nuclear Suppliers Group (NSG) commitments. The bottom line is that to date Russia has demonstrated less of a commitment to nonproliferation than did the Soviet Union.

The differences over exports to Iran (which also includes export of missile technology and conventional arms) have overshadowed some positive developments. Russia has tightened some of its export control laws and practices over the past few years. It has shown more willingness to cooperate with the United States on these issues. Also, Minatom officials and Russian specialists have tried to promote greater collaboration on proliferation risk analysis and nuclear power safety research and development. Moreover, there is reason to hope that Alexander Rumyantsev, the newly appointed head of Minatom, will be more attuned to U.S. concerns in this realm. During the time he was director of the Kurchatov Institute, his previous posting, that organization took pains to avoid dealings with Iran and other countries of proliferation concern.

Potential collaboration

Regardless of how the overall relationship between the United States and Russia develops, it is in the interest of the United States to have Russia be a responsible exporter of nuclear technologies. I believe resolution of the current export controversy requires closing the gap between the vastly different views of the virtues and prospects of nuclear power. Russia will most likely pursue its own development of nuclear power and expand its exports regardless of what we do. However, well-conceived cooperative efforts on our part may influence Russia's decisions.

Cooperative nuclear power development. Such cooperation may now be possible, because the Bush administration has a more positive view of nuclear power than did the Clinton administration. Cooperative efforts could begin quickly with a Russian-U.S. workshop to revisit the role that nuclear power may play in the 21st century to meet the world's energy and environmental needs. Such a technical workshop, which should be held immediately without preconditions, could then be expanded to include greater international participation. It may be advisable following such workshops to have the United States and other Western states support the development of next-generation reactors, such as liquid-metal cooled fast reactors or gas-cooled reactors, in Russia. Russia

could become an "extended workbench" for the West in reactor development, allowing its technical specialists and industrial firms to stay at the forefront of reactor development. It could also lead to an agreement of the "rules of engagement" for nuclear power exports.[31] I believe that Russia would take such efforts seriously, because the scale and scope of such projects rival the economic gains from cooperation with Iran and India.

Back-end fuel cycle collaboration. The most important issue in this area today is Russia's plan to import, store, and eventually reprocess spent fuel from around the world. The economic stakes for Russia are enormous, possibly amounting to $20 billion over the next 20 years, although most of the benefits could be achieved without the need to separate plutonium from any imported spent fuel. The United States has significant leverage, because most of the spent fuel that Russia wants to import is of U.S. origin and cannot be transferred to Russia without U.S. consent. A joint technical evaluation of the risks and benefits of such a project would be beneficial to both countries. If it appears technically attractive and politically plausible, the United States could condition its support upon Russian cooperation for nonproliferation. Minatom has claimed that some of the proceeds from this venture would be used to help remediate environmental problems in the nuclear complex. The United States could also insist that some of the proceeds be devoted to urgent nonproliferation problems. In addition, there would be substantial benefit for the United States to promote joint research activities in the area of waste management and disposition. This plan would also remove plutonium-bearing spent fuel from certain countries of potential proliferation concern, such as South Korea and Taiwan.

Joint proliferation risk assessment for nuclear power and fuel cycles. Russian specialists have developed very interesting ideas for risk assessment and proliferation-resistant fuel cycles that should be explored more globally. Joint projects between U.S. and Russian specialists in these areas could be an effective mechanism to discuss the very issues of concern regarding Russian exports to Iran. The projects should focus on proliferation risk analysis for both Iran and North Korea, thereby examining the logic and risks in both countries. As a condition for sponsoring such projects, the United States may insist on an interim agreement to limit current export of Russian technologies to the completion of the one Bushehr reactor, halting all other nuclear cooperation for the time being. Eventually, this approach could be a powerful tool to engage the Russians in analyzing their current nuclear agreements with 37 countries worldwide. In the spirit of cooperation, the same could be done for the United States.

Joint research on proliferation-resistant fuel cycles. The Russians have vigorously promoted such activities. At the United Nations, President Putin recently presented a new Russian proposal that is now being evaluated by the IAEA.[32] Many of the Russian projects funded by the International Science and Technology Center (ISTC) explore various pieces of this question. A serious, concerted joint effort in this area could greatly strengthen future nonproliferation regimes. It could also encourage a more thorough discussion of problems on the back end of the fuel cycle.

Joint research on reactor safety. Again, the Russians have promoted such joint work. Significant collaboration followed the Chernobyl accident. Several programs are still funded by the United States, but not at a level commensurate with the benefits. Many of the current efforts and proposals could be integrated into a more comprehensive collaboration. Russia could benefit from collaboration to help overcome its very negative nuclear safety image in the West. The principal benefits for the West are safer reactors in Russia and in the countries it supplies.

Joint export control center. Extensive export control discussions have taken place over the past decade. A center for export control has been set up in Moscow. These efforts should be enhanced.

All of the potential areas of collaboration are equally attractive for the ally and the status quo scenarios. To promote such collaborations may require substantial funds from the United States and other Western countries. In the adversary scenario, many of the collaborations are still advisable, but on a no-funds-exchanged basis, although it is difficult to envision a substantial presence of U.S. researchers and companies on Russian soil in that scenario. For a table summarizing the foregoing recommendations and those covered in the remainder of this article, see Appendix I.

PREVENTION OF LEAKAGE OF NUCLEAR WEAPONS KNOW-HOW

Adequate security for nuclear materials and nuclear know-how is not possible in the long term, if the

guardians of the weapons and materials and the stewards of the know-how are continually stressed to the breaking point. The U.S. government has oversimplified these concerns in denoting the Russian "brain drain" problem. However, the concern is much deeper and more serious than the typical characterization of how to prevent Russian nuclear weapons scientists from going to Iran, Iraq, or North Korea to help them in their quest for nuclear weapons. Not only can Russian nuclear workers help such countries quite effectively from their home base in Russia, but the brain drain mentality also ignores the potential proliferation risks posed by overly aggressive marketing of nuclear technologies and know-how by the leadership of the Russian nuclear institutes and sites. The focus on brain drain has placed emphasis on job creation for individual scientists in the Russian complex, which is too limited in scope and has not received much support in the U.S. Congress, especially in the light of the improving economic outlook in the closed cities.

Observations

Most Russian nuclear workers were buffered somewhat from the shock resulting from the collapse of the Soviet Union and subsequent economic chaos in Russia by the government's decision to keep the principal nuclear defense cities closed. They gained less freedom, but they retained better protection than most other Russians in both economic and security terms. The nuclear establishments no longer run the city administration and infrastructures in the closed cities, but widespread privatization has been slow. The strict security measures still in place stifle new business opportunities in these cities.

Nevertheless, the transition from lives of privilege during Soviet times to hardship in the 1990s was difficult. Until the last two years, the average monthly wage of nuclear workers was close to $50 per month. Retirees were lucky to get pensions of $20 per month. Even more devastating was the fact that the Russian Government was constantly in arrears in paying their wages. Paychecks were often late by four to six months, with inflation eating away at the already meager salaries. Moreover, the broad social safety net provided by the Soviet system that brought them guaranteed housing, rudimentary health care, and good education for their children was all but gone. The Russian nuclear workers have endured hardship without rebellion much beyond the ability of Westerners to grasp.

The scale of the Russian people problem in its nuclear complex is enormous.[33] The number of workers and facilities in the nuclear defense complex greatly exceed Russia's defense requirements for the foreseeable future. Minatom officials are implementing Russia's own nuclear conversion program against considerable odds. Civilian job creation in an economy as troubled as that of Russia is most difficult. Minatom officials are keenly aware of the dangers of social upheaval in the closed cities, because the workers remain underpaid, underemployed, and under appreciated.

To date, Minatom conversion efforts have met with mixed success. Some sites have been very aggressive in developing international contracts or finding a niche in the Russian economy. For example, in the closed city of Sarov (formerly Arzamas-16) the leadership of the Russian Federal Nuclear Center, VNIIEF, has increased annual funding from international contracts to $14 million.[34] Likewise, the leadership of the Avangard nuclear weapons production facility, with help from the DOE Nuclear Cities Initiative, has recently moved 500,000 square feet of manufacturing space outside its supersensitive security area. There is a keen recognition at the institutes that for the foreseeable future Russia will not need the large number of high-powered scientists and engineers left over from the Cold War days. There is similar, albeit less universal, recognition regarding production workers at the manufacturing plants. Although staffed with a well-educated and disciplined workforce, these plants are not competitive in the international commercial market. More troublesome is the fact that some of the nuclear sites are doing little on their own, waiting instead for the Russian government to bail them out.

The U.S. brain drain assistance programs have also had mixed success to date. Although initially viewed with great skepticism, the International Science and Technology Center (ISTC), a program designed to provide individual weapons scientists and engineers in the nuclear complex with civilian job opportunities, is now well regarded.[35] It has yet to build a sustainable base for Russian scientists, because it functions in a grant-making mode rather than a customer market-driven mode. The DOE Initiative for Proliferation Prevention (IPP) began with the right motivation, aiming to team up Russian institutes and Western businesses with the aid of the DOE laboratories. It has made good progress, but has been slowed down considerably in the Russian closed cities over disagreements of how U.S. funds should be

dispersed. Moreover, the scale of the effort has never been commensurate with the magnitude of the problem.

The newest of the people programs, the DOE Nuclear Cities Initiative (NCI), established a few years ago as a result of the effort of U.S. non-governmental organizations (NGOs)[36] at the height of economic stress in the closed cities, was well intentioned but handicapped from the beginning. The Russian government insisted, and the U.S. government agreed, to restrict these activities only to the "open" (meaning outside the fences of the nuclear installations) parts of the closed cities. The initial DOE focus was on brain drain and job creation rather than tangible, measurable benefits to U.S. national security, such as increased protection of nuclear materials or downsizing of the Russian nuclear complex.[37] The NCI program has received more criticism than support from the U.S. Congress.[38] Moreover, DOE and Minatom had very different views of priorities. DOE attempted to cast a broad net and involve many of its own laboratories in developing opportunities in the closed cities. Consequently, it placed very little of the initial NCI funds into the Russian cities themselves. Minatom officials, on the other hand, were concerned over U.S. attempts to gain broad access to the closed cities without first demonstrating that money would actually flow into the cities. Hence, they wanted to focus NCI efforts primarily on Sarov. These conflicts created an atmosphere of increasing hostility and mistrust between the Russian and U.S. government officials and have hampered progress.

The social dynamics in the closed cities appear to be very complex, reflecting perhaps a legacy of Soviet central control and rigid hierarchies. One typically finds little coordination among the cities' major players, such as the institutes, the production plants, the new private businesses, the city administrations and Duma, and the local universities. The lab-to-lab scientific exchanges with U.S. laboratories and the sister city programs that foster exchanges related to the social infrastructures in the cities have had a very positive effect on planning within these cities and on the outlook of their citizenry.[39] I should also note that the upturn of the overall Russian economy has eased considerably the economic stress on the nuclear workers over the past 18 months; salaries and pensions are up somewhat and they are being paid pretty much on time. The current situation is by no means good by U.S. standards, but appears to have stabilized.

Potential collaboration

The people dimension is crucial in dealing with all nuclear risks. It cannot be ignored or dismissed. The key question is whether or not U.S. financial assistance is necessary or desirable in helping Russia cope with its current people problems. Experience to date provides no clear answer. As a result of its improved financial situation, the Russian government may decide to forego U.S. assistance, because of the perceived lack of direct benefit from U.S. funds in creating new jobs and resentment over the intrusiveness of the U.S. government. Likewise, the U.S. Congress has questioned the need to provide U.S. funds if nuclear workers are now better paid and the nuclear institutes are recruiting new talent for stockpile stewardship. I believe that collaboration in the people area is desirable, but the programs should be tailored to fit current needs.

Nuclear cities conversion. In the ally and status quo scenarios, it is advisable to mount an industrial-scale defense conversion effort in the closed nuclear cities to help build sustainable civilian business activities. American industry generally avoids investment in Russia, as the potential returns are not commensurate with the risks. There are plenty of opportunities to invest in other countries of the world that have friendlier business climates than Russia. President George W. Bush or Vice President Dick Cheney would have to appeal to the chief executive officers (CEOs) of private U.S. companies, arguing that U.S. national security interests warrant a major initiative—for example, 100 U.S companies committing to explore business in the closed cities. The appeal could be backed up initially by assurances or a safety net provided by the U.S. government because of the increased risk of working in Russia, especially with its nuclear complex.

Although remote location and limited access represent serious obstacles for business development in the closed cities, there are some distinct advantages. The work force in these cities is very talented and disciplined, and the infrastructure and institutions associated therewith are generally much superior to those in the rest of Russia. The cities have relatively little crime and corruption and are well protected from undesirable outside elements. The U.S. government should continue to support infrastructure development in the closed cities and to provide assistance to reduce the risk for U.S. commercial investments. In addition, technical specialists

supported by the current NCI program could help facilitate initial discussions with U.S. industry and provide a bridge from the closed institutions to U.S. industry.

For example, a few pilot projects could be funded to demonstrate the benefits of working in the closed cities. The NCI-funded Open Computing Centers in Sarov and Snezhinsk and the initial development of the Sarov Technopark have laid an excellent foundation for such efforts. These efforts along with IPP projects could be expanded to develop open research centers in Sarov and Snezhinsk that would enable the commercialization of research services from the Russian institutes.[40] Such efforts would then be turned over to U.S. industry to develop further as business opportunities dictate. A Western influx of management and marketing expertise supplemented by venture capital investments would be very helpful. A serious, concerted effort that involved major American industry players could also help to overcome the access problems in the closed cities. The ISTC and IPP programs should be continued, but directed at a customer-provider relationship with emphasis on sustainability. A major industrial initiative is not advisable in the adversary case, because it would not be possible to create a supportive business climate.

Joint defense conversion study. In the most optimistic case, the U.S. government could attempt to engage the Russian government in jointly analyzing their mutual defense needs and the resulting requirements for their nuclear complexes. Such an effort would build a much stronger mutual understanding of the defense conversion needs and the challenges faced by each side. Such an effort could start with a joint study of how we got to where we are today.[41] It would also provide information essential to achieving parity in nuclear weapons production capacity.[42]

Expanded social infrastructure and people exchange programs. The U.S. government has devoted only modest funds to date for these efforts, but results have been encouraging because these efforts are leveraged by the work and good will of the sister city participants. The sister city efforts have engaged the entire gamut of the social infrastructure in a few of the closed cities, such as Sarov. These programs should be expanded to cover other concerns in the closed cities, such as how to deal with the retired work force. For example, sharing U.S. defense worker transition experience would prove useful. Much greater effort should go to sponsor people exchange programs to support young citizens of the closed cities for extended stays in the United States to help strengthen long-term democratic institutions and practices in Russia. This program can be patterned after the one run by the Library of Congress for Russia in general. Enhancing social infrastructure and people exchange programs to strengthen the democratic institutions in the closed cities is advisable under all scenarios.

Expansion of nuclear complex conversion to other sites. If nuclear conversion efforts in the closed cities are successfully demonstrated, then it would be advisable to extend the conversion efforts to other, often neglected, parts of the former Soviet nuclear defense complex that may also pose a proliferation threat. Many of the key scientists and engineers in the greater Soviet nuclear complex worked for institutes outside the closed cities. Their knowledge and/or access to nuclear materials also pose a significant threat. These workers have been much less protected that those in the closed cities and, consequently, may have already found other gainful employment. In the ally and status quo scenarios a joint Minatom–DOE study should be conducted to identify the residual threat and then consider extending the industrial conversion approach proposed above to those institutes/cities that are nuclear but not closed, and those institutes/cities that are closed but not nuclear. Such an effort is not advised in the adversary case, because a supportive environment would not exist.

DOWNSIZE NUCLEAR MATERIALS INVENTORIES AND PRODUCTION CAPACITY

The huge amounts of nuclear materials and the enormous production capacity for nuclear weapons in the Russian complex represent a longer-term concern for the United States unlike the security of nuclear weapons, materials, and know-how, which along with nuclear exports, represent an immediate proliferation threat. Asymmetry in nuclear materials inventories and production capacities is an arms control concern that becomes more important if deep cuts in strategic arsenals are implemented. Currently, the Russian nuclear complex has significantly more material and greater production capacity, especially for pit manufacture, than the U.S. complex. Also, the ability to reconstitute a larger arsenal is likely to become an important consideration once deep reductions are implemented.

A significant reduction in materials or production capacity will take time, especially for the conversion of

HEU or the disposition of plutonium. In addition, the threat removed by such efforts must be put into the context of the threat from the remaining inventories and capacities. Hence, these efforts fall within the framework of opportunities that help shape the future security environment, rather than actions that address a clear and present danger. Although not urgent, these issues are important. Collaboration to address these risks has important symbolic value, not only to the United States but also to the rest of the world. Moreover, collaboration in these areas, if done correctly, may help to bolster the case for nuclear power, because it demonstrates how the engines of the Cold War can be reversed to fuel clean energy and promote prosperity for mankind.

Observations

Russian officials admit they have plenty of plutonium, HEU, and tritium, although the amount, location, and other technical details are still kept secret. They see no need to dispose of excess plutonium, because they view plutonium as a resource. Plutonium was very expensive to produce, hence they expect to extract as much of its energy content as possible. Extracting energy from weapons-usable HEU is easy by down-blending to low enriched uranium (LEU) reactor fuel. Moreover, it is economically attractive. Plutonium is more difficult, because it must be burned in reactors to make it unattractive for weapons use. In today's market, converting plutonium to reactor fuel is economically unfavorable. The Russians have rejected the alternative of immobilizing plutonium with high-level waste to make it unattractive for weapons use. Hence, the Russians prefer to store the plutonium excess to their weapons needs and burn it in future fast reactors, preferably as start-up material for a breeder reactor economy.

In the early 1990s, Russia declared 500 MT of HEU excess to its weapons program and agreed to a financially lucrative deal with the United States (originally estimated at $12 billion over 20 years) to blend it down to LEU for the uranium fuel market.[43] After protracted negotiations, Russia and the United States also recently agreed to dispose of 34 MT of plutonium by burning it in reactors or, for the United States, disposing some of the lower-grade plutonium by immobilizing it with high-level waste, although this aspect of the agreement is now in abeyance.[44] The Russians insist that any cost associated with burning plutonium faster or with less energy extraction than they believe to be desirable must be borne by the United States. The most recent Russian estimate for Western assistance to burn up the 34 MT of plutonium according to current Western plans is approximately $2 billion. The Russians believe that arms control is achieved principally by limiting delivery vehicles, not by limiting warheads, fissile materials, or production capacity. There is very little enthusiasm for a second phase of plutonium disposition in Russia, because officials there do not view the size of plutonium inventories to be of central concern to arms control.

A huge disparity remains in production capacity for nuclear weapons components and assembly between Russia and the United States. The Russians plan to size their production complex based on defense requirements and economics, rather than on arms control considerations. Since Russia's capacity far exceeds its requirements and its ability to pay for it, it is in the process of converting the plutonium production facilities at Zheleznogorsk (Krasnoyarsk-26) to civilian applications and to convert two of its four serial production nuclear plants (Avangard in Sarov and Start Production Enterprise in Zarechny/Penza-19).[45] Nevertheless, the remaining defense facilities are able to produce and assemble nuclear weapons materials and components, at capacities many times that of the United States.

In spite of many difficulties, the HEU/LEU purchase agreement has been very successful. Russia has taken more than 100 MT of HEU out of the weapons stream and delivered LEU to the United States for commercial power reactors with a return approaching $2 billion.[46] Nevertheless, the difficulties encountered when the United States privatized its uranium enrichment operations at a time of declining prices for uranium and for enrichment services demonstrated the potential fragility of such deals. The HEU/LEU purchase also allowed Minatom to transition many of its employees from defense to civilian work without traumatic social consequences in a few cities, such as Seversk (Tomsk-7). My Russian colleagues in other closed cities have also indicated that Minatom is channeling some of the proceeds of this deal to support conversion activities in their cities. Moreover, downblending HEU reduces future safeguards requirements in the Russian complex.

The various plutonium collaborations have not fared as well. Negotiations on plutonium disposition have been exceedingly complex and drawn out by the Russians, who have also dragged their feet in many of the collaborative technical projects. The price tag for disposition

has continued to swell as a result. The U.S.-sponsored project to convert the cores of the three remaining plutonium-producing reactors—to reduce the production of plutonium—has been even more problematic. Most Russians considered this an unattractive idea from the beginning. Nevertheless, with American insistence and funding, various schemes for core conversion were investigated, although they have apparently now been abandoned in favor of constructing fossil fuel plants to replace the heat and electricity provided by the production reactors. The most recent initiative, a plan promoted by former Russian Minister of Atomic Energy Adamov and the Clinton administration to place a moratorium on reprocessing of civilian spent fuel in return for U.S. funding of up to $100 million to help store such fuel and finance joint nuclear research projects, was also received with skepticism in most of Russia's nuclear complex. Several of my Russian colleagues pointed out that a ban on reprocessing contradicts the Russian view of the future of nuclear power, but was being considered only because of the substantial financial incentive involved. In spite of a substantial financial carrot being offered by the United States for various plutonium projects, most Russians in the defense complex do not believe that these projects are in Russia's best interest. New leadership at Minatom may temper this orientation, but it is too soon to tell.

In all of these longer-term disposition efforts we must keep in mind that the materials under consideration for blend-down or reactor burning are most likely among the best protected nuclear materials in the Russian complex. The United States must not lose sight of the fact that protection is the most urgent concern. Also, we must carefully evaluate the disposition options to make certain that the process of disposition does not actually create a greater nuclear materials safeguards problem than it solves.

Potential collaboration

Accelerated HEU conversion. The conversion of weapons-grade uranium to civilian reactor fuel remains one of the most attractive and sustainable collaborations. It provides nonproliferation benefits to the world and allows Russian workers to remain employed and paid. The two governments should do everything to stay on track with the current HEU/LEU agreement. In addition, mechanisms should be examined to accelerate the blend-down of the HEU under agreement and consider adding more to the initial 500 MT. Such efforts may require assistance in the form of grants or loans to Minatom to add equipment and facilities. However, the economic implications of an accelerated schedule must be carefully analyzed beforehand. The rate of blend-down must be carefully coupled to the rate of LEU sales, considering the current market constraints. It is possible that increased sales on some appropriate time schedule may—at the right price—be very attractive to international customers, such as Japan. Acceleration of HEU conversion is advisable for both the ally and status quo scenario with some possible U.S. financial assistance. It is also advisable in the adversary scenario, but without U.S. financial assistance.

Bilateral fissile materials data exchange. Secrecy surrounding Russian inventories of plutonium remains a major barrier to further progress in this area and in the MPC&A collaborations. Minatom opened the door to collaboration recently when it approved a civilian plutonium registry project. Russian technical specialists, with U.S. support, will study and analyze Russian nuclear materials production and utilization outside their nuclear weapons program with the objective of determining the historical plutonium material balance.[47] Successful conclusion of this project, along with high-level diplomacy, may make it possible to begin a similar project for all Russian plutonium. DOE has shared its experience, including its classification concerns, in conducting the "Plutonium: The First 50 Years" review.[48] Such a project is advisable in all scenarios but very unlikely for weapons inventories in the adversary case.

Reconsideration of plutonium disposition strategy. It is time to revisit the plutonium disposition strategy. Both countries have new administrations, and new leaders are in charge of Minatom and DOE. The projected costs of the disposition options on both sides have risen dramatically. Technical leaders of the Russian nuclear complex have generally been opposed to the U.S. plan to use Russian light-water reactors to burn their plutonium, preferring either fast reactors or possibly developing fuel for gas-cooled reactors. I believe that the most important aspect of plutonium disposition is to accelerate the conversion of plutonium from weapons to shapes capable of being inspected, followed by monitored storage. Such a strategy could justify immediate construction of a second wing at the Mayak fissile materials storage facility, or some less expensive alternative. A joint working group should be tasked immediately to re-examine plutonium disposition options under all three scenarios.

Innovative plutonium solutions. In all three scenarios, it would be prudent to explore innovative (perhaps radical) ideas that address getting plutonium out of the Russian weapons program and achieving parity with the United States. Buying Russian plutonium is one such possibility, but it is unlikely. Another option is to encourage the Russians to store plutonium excess to their weapons needs in an internationally safeguarded facility—a "plutonium bank"—on Russian soil (perhaps in the first or a second wing of the Mayak fissile materials storage facility) for future withdrawal for nuclear power development, when economics are more favorable. Western governments would provide loans to Russia, with plutonium held as collateral until withdrawal. If the U.S.-Russian relationship becomes adversarial, Russia would probably not cooperate with such a program.

Revisit core conversion and civilian reprocessing moratorium. With new administrations in place both in Russia and the United States, it is advisable under all three relationship scenarios to jointly revisit the objectives of these programs. Renewed efforts should be made to help the Russians shut down the remaining three plutonium production reactors as soon as possible, rather than opt for core conversion. Current efforts to replace these reactors with conventional power plants should be expedited as well. Concurrently, every effort should be made to persuade Russia to place the plutonium produced during the final years of operation into the international safeguards regime.[49] Similarly, the overall benefits of financially supporting a Russian moratorium on reprocessing civilian spent fuel should be revisited and compared to the benefits of providing enhanced safeguards.[50] These issues should be discussed in conjunction with a re-examination of the U.S. position on the nuclear fuel cycle.

Production capacity parity. Although Russian officials are fundamentally opposed to the concept of parity in production capacity, it may be possible to engage the Russians in a joint study of the nuclear defense needs of each country and the accompanying production complex conversion challenges.[51] First Deputy Minister of Atomic Energy Lev Ryabev has also opened the door in this arena by expressing his support for a very informal joint Russian-U.S. study of defense conversion experiences.[52] This study should be initiated, and then followed by possible extension to defense needs. Any serious effort on behalf of the United States to assist Russia with the conversion of its nuclear defense complex must include such a joint study. Such collaborations become very important if deep reductions in nuclear arsenals are pursued by Russia and the United States and hence are advisable in all three scenarios, but unlikely in the adversary case.

HELP PREVENT NUCLEAR ACCIDENTS AND ENVIRONMENTAL DISASTERS

In the nuclear business, anyone's accident is everyone's accident, whether they involve reactors or weapons. Such accidents may endanger populations outside of Russia (as in the Chernobyl accident), and they most likely will negatively impact public acceptance of nuclear power everywhere. A serious accident in either the Russian or U.S. nuclear weapons complex could lead not only to human tragedy, but also undermine public support for nuclear stewardship. Consequences from environmental disasters are typically more localized, but some Soviet practices such as nuclear dumping in the arctic seas and nuclear test practices at the Semipalatinsk test site in Kazakhstan have international implications.

Observations

The Soviet and Russian record on nuclear warhead safety is very good. However, the Russian approach to nuclear facilities operations and industrial safety is still of the Manhattan Project era. The Russian nuclear complex has been willing to live with much greater risks and vulnerabilities than their American counterparts; their facilities today do not meet modern Western safety and environmental standards. During Soviet days, the needs of the state were placed far above health and safety concerns. A recent Soviet historical account of early plutonium production compared plutonium workers to "soldiers storming a hill."[53] From this point of view, one expects some casualties to achieve victory. The health and safety record of the Russian complex reflects this philosophy. Plutonium workers suffered heavy radiation exposure on the job, and the public was endangered by major accidents at Mayak in 1957 and 1967.[54]

The Chernobyl accident brought to light poor operational practices and disregard for inherent safety in some Russian reactor designs. While improvements have been made, reactor safety standards in Russia still lag behind Western standards. These problems are exacerbated by the personal hardships suffered by nuclear reactor workers in Russia and the NIS.

Environmental practices in the Soviet nuclear complex were even worse than safety practices, as there was general disregard for the environmental impact of the nuclear complex. Although the cleanup problem is enormous, it is not high on Russia's list of priorities today.[55] Environmental groups have begun to put pressure on the Russian government, but to date have had little influence. There is a natural reluctance for the West to finance the clean up of the mess made by the Soviet Union. Nevertheless, that "mess" also represents a wealth of scientific information that could be extremely useful to the United States in understanding and dealing with the environmental and health effects of nuclear contamination and ionizing radiation in the United States. Some collaborative efforts in reactor safety and in environmental areas have been developed over the past eight years. However, the scale of these efforts is not commensurate with the potential benefits of collaboration.

Potential collaboration

It is within the scope of U.S. interest that another Chernobyl accident or a major nuclear weapons or facility accident in Russia or the NIS be avoided. Collaborative health and environmental programs can be tailored to help Russia, while concurrently extracting valuable information for our own programs. Most collaboration can be conducted with international participation. Bilateral efforts may be needed for facilities or information the Russians consider too sensitive to share with the international community.

Environmental R&D collaboration. Under all three scenarios, it is advisable to charter a technical working group now to develop substantially increased environmental collaborations that benefit both Russia and the United States. Such a working group should be chartered by developing a joint R&D program that allows us to share environmental databases and conduct research to understand and mitigate the effects of radioactive contamination. The United States could share its extensive experience in developing its own environmental assessment and remediation program. I believe that DOE would be wise to invest more of its $300 million per year environmental R&D budget in Russia, both to support Russian and U.S. researchers who could learn from the wealth of environmental information there.

Collaboration for nuclear accident prevention. Current reactor safety cooperation should be expanded.[56] A technical working group should be chartered to examine additional cooperative measures to prevent nuclear accidents at defense and civilian nuclear facilities. International organizations should be included in the working group on civilian facilities. Such collaboration is advisable in all three scenarios, but will necessarily be limited on the defense side for the adversary case.

Collaboration on health effects. Charter a new working group for a current assessment of what can be learned from Soviet and Russian nuclear worker experience and from health effects resulting from radioactive contamination. Initial results from the limited cooperation to date indicate that Soviet experience may help to re-evaluate the currently used linear no-threshold model for the effects of ionizing radiation on humans.[57] It may be advisable to establish a joint radiation health center that would help to institutionalize collaboration between the two countries. Cooperation on nuclear health effects is advised in all three scenarios.

Nuclear complex cleanup. Establish a technical working group on issues, concerns, and common elements of the cleanup challenges in the former Soviet and U.S. nuclear complexes. The United States could share its experience, including both successes and lessons learned from difficulties. Such an effort may lead to an increased international effort to help finance remediation of environmental problems with greatest international impact, such as those in the arctic seas and the former Soviet nuclear test site in Kazakhstan. Such cooperation is advisable in all three scenarios, although substantial financial assistance in the adversary scenario is unlikely.

CONCLUSION

The analysis presented here, based on the risk that Russia's nuclear complex poses to the United States, makes clear that increased nuclear cooperation with Russia will enhance U.S. national security. Many of the suggested collaborations fall into the category of urgent: they address the clear and present proliferation dangers that remain ten years after the breakup of the Soviet Union. Others address longer-term issues of arms control, stability, and irreversibility that offer opportunities to help shape the future direction of Russia's nuclear programs. Most areas of nuclear cooperation are advisable in both the ally and status quo relationship scenarios, and many are advisable even in the adversary scenario, because they strongly serve the interests of the United States. United States National Security Advisor Condoleezza Rice's statement that "American security

is threatened less by Russia's strength than by its weakness and incoherence" is certainly true in the nuclear arena.[58] We have much more to gain through nuclear cooperation than we have to lose. I believe that if the Bush administration moves aggressively to promote nuclear weapons and power cooperation along the lines of the "ally" scenario, it can decisively and positively influence the direction of the Russian nuclear program. Intensifying such cooperation may also help to reverse the tensions built up between the two governments over the past few years.

The United States can tackle the difficult problems posed by the Russian nuclear complex only by cooperation, not by unilateral action. Nuclear cooperation has become more difficult during the past two years because of the increased tensions between Russia and the United States and owing to Russia's improved economic condition. Today, nuclear cooperation depends more on reestablishing trust and partnership than simply increasing U.S. funding. Some of the most difficult and sensitive issues in areas such as nuclear materials protection will benefit substantially from renewed informal discussions between specialists in the field as well as by a step-by-step approach to cooperation. We must also recognize that Russian priorities may not fit neatly into the U.S. priority scheme, but we should always view potential collaboration within the strategic framework, tailoring each opportunity to provide as much benefit as possible to the highest priority risks. We should judiciously invest U.S. funds to help curb current risks and pursue future opportunities. Some areas of cooperation may not require any U.S. investment, whereas others may require significant increases, and some are best addressed with international support.

Most importantly, the U.S. government must view nuclear cooperation with Russia as one of the principal factors shaping our future security environment and act accordingly. We have been lucky that despite the chaotic breakup of the Soviet Union during the last ten years, nothing terrible has happened in the Russian nuclear complex. But over that same decade, the United States has lost many opportunities to positively influence Russia's future direction. We can no longer count on luck to prevent disaster, nor should we pass up the opportunity to help shape Russian nuclear policy before the window of opportunity closes. The Bush administration must now provide the leadership for a renewed bipartisan effort to rethink and intensify nuclear cooperation with Russia. If the Bush administration can generate strong support in Congress for such a policy and establish a management structure that puts someone in charge to integrate and coordinate the disparate programs and objectives of the various executive branch agencies, properly targeted cooperative activities with Russia will enhance U.S. and, indeed, global security.

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[1] The author wishes to thank Mark Mullen and James Toevs of the Los Alamos National Laboratory for helpful discussions leading to the development of many of the ideas presented here. He also thanks Matt Bunn, Leonard Spector, and William C. Potter for their critical reading of the manuscript and their helpful comments and suggestions.

[2] For a history of the Nunn-Lugar legislation see Richard Combs, "U.S. Domestic Politics and the Nunn-Lugar Program," in John M. Shields and William C. Potter, eds., *Dismantling the Cold War: U.S. and NIS Perspectives on the Nunn-Lugar Cooperative Threat Reduction Program* (Cambridge, MA: MIT Press, 1997), pp. 41-60. For a recent review of the Cooperative Threat Reduction program see John W.R. Lepingwell and Nikolai Sokov, "Strategic Offensive Arms Elimination and Weapons Protection, Control, and Accounting," *The Nonproliferation Review* 7 (Spring 2000), pp. 59-75. In 1996, Nunn-Lugar legislation was extended to the Nunn-Lugar-Domenici legislation for a broader range of cooperative programs.

[3] In the nuclear weapons area, the informal scientific exchanges between the United States and Russia began with the exchange visits of the directors of the U.S. and Russian nuclear weapons laboratories in February 1992. For reference to some of the initial discussions and reactions of these visits, see Siegfried S. Hecker, "An American Tribute to Yuli B. Khariton," paper presented at a conference honoring the 95th anniversary of the birth of Yuli B. Khariton, LA-UR-99-0884, Sarov, Russia, February 27, 1999.

[4] Project Sapphire involved the removal of approximately 600 kg of HEU from the Ulba Metallurgical Plant in Kazakhstan in 1994. See Emily E. Daughtry and Fred L. Wehling, "Cooperative Efforts to Secure Fissile Materials in the NIS," *The Nonproliferation Review 7* (Spring 2000), pp. 97-111; and William C. Potter, "Operation Sapphire: U.S.-Kazakhstani Cooperation for Nonproliferation," in Shields and Potter, eds., *Dismantling the Cold War*, pp. 344-362.

[5] Following the exchange visits of the laboratory directors in February 1992, the U.S. and Russian nuclear weapons laboratories began a series of joint scientific experiments through a process called lab-to-lab collaboration. These collaborations built respect and trust that led to the Department of Energy's lab-to-lab MPC&A program initiated by then Under Secretary of Energy, Charles B. Curtis. The first lab-to-lab MPC&A contracts were signed between Los Alamos and VNIIEF/Arzamas-16 and Los Alamos and the Kurchatov Institute in June 1994.

[6] Initially the leadership of Minatom was slow to begin downsizing key nuclear defense facilities, hoping that defense orders would soon pick up. However, downsizing efforts became serious later in the 1990s as the Russian government's economic situation worsened. See Oleg Bukharin, "Downsizing Russia's Nuclear Warhead Production Infrastructure," *The Nonproliferation Review* 8 (Spring 2001), p. 116.

[7] A number of confirmed thefts of nuclear materials occurred in 1993 and 1994. For a recent discussion of nuclear smuggling attempts see Rob Edwards, "Nuclear Boom," *New Scientist Magazine*, May 9, 2001.

[8] Most of the GAO audits have been very critical of the Russian cooperation programs. See for example, U.S. General Accounting Office, *Nuclear Nonproliferation: Limited Progress in Improving Nuclear Material Security in Russia and the Newly Independent States,* GAO/RCED/NAISD-00-82, March 16, 2000, <http://www.gao.gov>.

[9] Oleg Bukharin, Matthew Bunn, and Kenneth N. Luongo, *Renewing the Partnership: Recommendations for Accelerated Action to Secure Nuclear*

Material in the Former Soviet Union, Report of the Russian American Nuclear Security Advisory Council, Princeton, New Jersey, August 2000.

[10] Jonathan Alter, "The American and Russian People Don't Want a New Confrontation," *Newsweek*, April 27, 2001 quotes Mikhail Gorbachev as being optimistic about the roots of democracy in Russia, despite recent pessimistic predictions.

[11] Jeffrey Taylor, "Russia is Finished," *Atlantic Monthly* 287 (May 2001), p. 35.

[12] The author first traveled to Russia as part of the exchange visit of nuclear weapons directors in February 1992. Since that time he has made over 20 visits to the nuclear complexes of Russia and Kazakhstan.

[13] Bukharin, "Downsizing Russia's Nuclear Warhead Production Infrastructure," p. 116.

[14] For an excellent discussion of current strategic stability issues see Camille Grand, "Ballistic Missile Threats, Missile Defenses, and Strategic Stability," in *International Perspectives on Missile Proliferation and Defenses*, Occasional Paper No. 5 (Monterey, CA: Monterey Institute of International Studies and University of Southampton, UK, March 2001), pp. 5-11.

[15] The observations by the author are based on his interactions with leaders and scientists of the Russian nuclear weapons complex, both the nuclear weapons institutes, and some of the production facilities.

[16] The Soviet weapons capability for beryllium was located at the Ulba Metallurgical Plant in Ust-Kamenogorsk, now in Kazakhstan.

[17] *The Agreement between the Government of the United States of America and the Government of the Russian Federation on the Exchange of Technical Information in the Field of Nuclear Warhead Safety and Security* was signed by U.S. Secretary of Energy Hazel O'Leary and Russian Minister of Atomic Energy Viktor Mikhailov in December 1994 and entered into force in June 1995. First Deputy Minister of Atomic Energy Lev Ryabev and U.S. Assistant Secretary of Energy for Defense Programs Victor Reis met in London in December 1995 and again in Moscow in June 1996 and agreed on a framework for technical collaborations to deal with the challenges of the CTBT. These agreements together were codified as the Reis/Ryabev cooperation, and later the Moniz/Ryabev cooperation.

[18] Lepingwell and Sokov, "Strategic Offensive Arms Elimination," p. 59.

[19] An excellent review of the issues is presented by Mathew Bunn and John P. Holdren, "Managing Military Uranium and Plutonium in the United States and the Former Soviet Union," *Annual Review of Energy and Environment,* 22 (1997), p. 403. A more recent and very complete update is given by Bukharin, Bunn, and Luongo, *Renewing the Partnership.*

[20] The initial plans of the DOE MPC&A program are captured in *Unified U.S.-Russian Plan for Cooperation on Nuclear Materials Protection, Control, and Accounting (MPC&A) between Department of Energy Laboratories and the Institutes and Enterprises of the Ministry of Atomic Energy (Minatom) Nuclear Defense Complex, Report of the Joint U.S.-Russian MPC&A Steering Group*, September 1, 1995.

[21] Observations based on the author's discussions with Russian specialists and as reported by Bukharin, Bunn, and Luongo, *Renewing the Partnership*.

[22] Sam Nunn, Chair, *Managing the Global Nuclear Materials Threat, Report of the CSIS Project on Global Nuclear Materials Management (*Washington, DC: Center for Strategic and International Studies, January 2000), <http://www.csis.org/pubs/gnmmthreat.html>. See also Howard Baker and Lloyd Cutler, co-chairs, U.S. Secretary of Energy Advisory Board Report, "A Report Card on the Department of Energy's Nonproliferation Programs with Russia," January 10, 2001, <http://www.hr.doe.gov/seab>; and Bukharin, Bunn, and Luongo, *Renewing the Partnership*.

[23] The CTR and DOE nuclear cooperation programs in Russia have been remarkably devoid of corruption.

[24] The threat from radioactive dispersal devices is discussed in Defense Science Board 1997 Summer Study Task Force*, DOD Response to Transnational Threats, Vol. I, Final Report,* October 1997. See also, James L. Ford, *Radiological Dispersal Devices: Assessing the Transnational Threat* (Washington DC: National Defense University, March 1998).

[25] Programs to consolidate and eliminate many of the most vulnerable nuclear materials in Russia and the other NIS have been suggested by William C. Potter of the Center for Nonproliferation Studies of the Monterey Institute of International Studies in a number of presentations; including William C. Potter and Fred L. Wehling, "Sustainable Nuclear Material Security in Russia: Commitment, Consolidation, and Culture," paper presented at the American Association for the Advancement of Slavic Studies, 31st National Convention, St. Louis, Missouri, November 18-21, 1999. See also Mark Mullen, in *Improving the Security of Weapons-Usable Uranium in the Former Soviet Union: Next Steps* (Los Alamos, New Mexico: Los Alamos National Laboratory, 1998), and Matthew Bunn, *The Next Wave: Urgently Needed New Steps to Control Warheads and Fissile Materials,* (Washington DC: Carnegie Endowment for International Peace and Harvard University, 2000), <http://www.ceip.org/files/projects/npp/pdf/NextWave.pdf>.

[26] Daughtry and Wehling, "Cooperative Efforts to Secure Fissile Materials in the NIS," p. 97.

[27] See for example, Bill Broad, "Document Reveals 1987 Bomb Test by Iraq," *New York Times*, April 29, 2001; and Charles Arthur, "Terrorists' Dirty Bomb is Nuclear Nightmare," *Independent* (London)*,* May 24, 2001.

[28] The non-conventional MPC&A ideas and others were presented in Siegfried S. Hecker, Mark F. Mullen, and James W. Toevs, "Next Steps for Nuclear Materials Management in Russia and Other States of the Former Soviet Union," Los Alamos National Laboratory Report LA-UR-01-2508, April 2, 1998.

[29] Russia has more than 300 ports of entry, many of them along its troubled southern border.

[30] Russian officials have remarked to the author on many occasions that they viewed the Clinton administration's views on nuclear power, especially those of Vice President Gore, as very negative. Hence, they viewed with great suspicion many of the major U.S. initiatives for nuclear cooperation. During the second term of the Clinton administration, the U.S. view toward nuclear power became somewhat more balanced, with several senior officials strongly promoting its future. However, overcoming the initial negative impressions on the Russian side remained difficult.

[31] During 1999 and 2000, the U.S. government attempted to develop such rules of engagement with Russia concerning Iran, offering various forms of nuclear power cooperation, but the Russian government refused to cooperate.

[32] President of the Russian Federation Vladimir Putin, "Address to the Millennium Summit," United Nations, New York, New York, September 6, 2000, <http://www.un.org/millennium/webcast/indexe.htm>.

[33] Bukharin, "Downsizing Russia's Nuclear Warhead Production Infrastructure," p. 116; Lev Ryabev, "We Must Save the Best," *Gorodskoy Kuryer (Sarov),* March 5, 1998; Anatoly Dyakov, paper delivered to Princeton Conference on Helping Russia Down-size its Nuclear Weapons Complex, Princeton University, March 14, 2000. A good summary is presented in "Helping Russia Downsize its Nuclear Complex: A Focus on the Closed Nuclear Cities, Report of an International Conference held at Princeton University, March 14-15," Princeton University, June 2000.

[34] VNIIEF/Arzamas-16 officials (names withheld on request), correspondence with the author, March 2001.

[35] U.S. participation in the ISTC, which is a multilateral organization, is managed by the Department of State. For a discussion of the early history of the ISTC program see Glenn E. Schweitzer, *Moscow DMZ: The Story of the International Effort to Convert Russian Weapons Science to Peaceful Purposes* (Armonk, New York: M.E. Sharpe, 1996); and R. Adam Moody, "The International Science Center Initiative," in Shields and Potter, eds., *Dismantling the Cold War,* pp. 251-290.

[36] The initial Nuclear Cities Initiative was developed by non-governmental organizations, mostly affiliated with the Russian-American Nuclear Security Advisory Council.

[37] For a more comprehensive nuclear cities plan, see Siegfried S. Hecker, Mark F. Mullen, and James W. Toevs, "Nuclear Cities Initiative*,"* Los Alamos National Laboratory Report LAUR-01-2507, March 30, 1998.

[38] The NCI program faced an uphill struggle from the beginning, because it had little congressional support. In fact, the program was evaluated in a critical GAO audit even before it was allowed to spend any program funds. See U.S. General Accounting Office, *Nuclear Nonproliferation, Concerns with DOE's Efforts to Reduce the Risks Posed by Russia's Unemployed Weapons Scientists*, GAO/RCED-99-54, February 1999, <http://

www.gao.gov>. The most recent audit was just released: U.S. General Accounting Office, "*Nuclear Non-proliferation: DOE Efforts to Assist Weapons Scientists in Russia's Nuclear Cities Face Challenges*," GAO-01-429, May 3, 2001, <http://www.gao.gov>.

[39] During a visit to Sarov in March 2000, Anatoly Amelichev, head of the city Duma, commented to the author and colleagues that "…your cooperation with us is more important than the money you bring."

[40] Siegfried S. Hecker and James W. Toevs, "Accelerated Conversion Plan for Sarov," paper delivered to Princeton Conference on Helping Russia Downsize its Nuclear Weapons Complex, Princeton University, March 14, 2000; James W. Toevs, "Sarov, Russia: Accelerated Job Creation and the Open Computing Center, " paper delivered to the Institute for Nuclear Materials Management Conference, July 2000, New Orleans, Louisiana.

[41] In 1999, Minatom First Deputy Minister Lev Ryabev and DOE Assistant Secretary Rose Gottemoeller approved a joint study of defense conversion led by A.N. Antonov from Minatom and Siegfried S. Hecker from Los Alamos National Laboratory. This study has been very slow to get off the ground because of the increasing tensions between the two governments.

[42] The current imbalance in production capacity is enormous. The Russian complex is still able to produce thousands of plutonium pits per year, whereas the United States has not built a pit in 13 years and is just now re-establishing the ability to build a few per year. Russia still has four nuclear weapon assembly/disassembly plants (although it is phasing out two of them); the United States has one.

[43] The idea of the HEU/LEU deal is credited to Thomas L. Neff, "A Grand Uranium Bargain," *New York Times,* Oct. 1, 1991. The HEU/LEU deal is also discussed in Bunn and Holdren, "Managing Military Uranium and Plutonium in the United States and the Former Soviet Union," and in Richard A. Falkenrath, "The HEU Deal," in Graham T. Allison, et al., eds., *Avoiding Nuclear Anarchy* (Cambridge, MA: MIT Press, 1995), p. 229. A recent update is presented in Thomas L. Neff, "Privatizing National Security: the U.S.-Russian HEU Deal at Risk," *Arms Control Today* 28 (August/September 1998), <http://www.armscontrol.org/ACT/augsep98/tnas98.htm>.

[44] *Agreement Between the Government of the United States and the Government of the Russian Federation Concerning Management and Disposition of Plutonium Designated as No Longer Required for Defense Purposes and Related Cooperation*, September 1, 2000.

[45] Bukharin, "Downsizing Russia's Nuclear Warhead Production Infrastructure."

[46] Bunn, *The Next Wave*.

[47] The Plutonium Registry project is a pilot project being conducted jointly between Minatom and DOE (Andrew Bieniawski, DOE program manager and Mark Mullen of the Los Alamos National Laboratory, principal investigator).

[48] U.S. Department of Energy, *Plutonium: The First 50 Years* (Washington, DC: U.S. Government Printing Office, 1996).

[49] During a visit to the Siberian Chemical Combine in Seversk (Tomsk-7) in Nov. 1997, the author was shown the current storage facility for plutonium produced by the two production reactors at the combine. The plutonium stored there appears to be among the best protected in the Russian nuclear complex.

[50] In May 2001, correspondence with the author, Matthew Bunn of Harvard University pointed out the collateral benefits of shutting down Russia's civilian nuclear reprocessing; namely, the materials safeguards at these facilities are poor and their health, and environmental records are abysmal.

[51] The Russians take a fundamentally different approach to their stockpile, remanufacturing their weapons on a 10-year time cycle. Hence, Russian officials argue that they would need "functional" parity, taking into account the inherent differences in the U.S. and Russian stockpiles. Moreover, the United States would maintain a significant "hedge" capability in reserve warheads under START II reductions, which the Russians claim offsets their production capacity advantage.

[52] This study was described in footnote 41.

[53] F.G. Reshetnikov, "On the Fiftieth Anniversary of the Development of the Atomic Bomb," *Atomic Energy* 87 (1999), p. 619.

[54] Siegfried S. Hecker, "The Plutonium Challenge: Environmental Issues," *Los Alamos Science* 26 (2000), p. 36.

[55] However, during the author's first visit to Snezhinsk/Chelyabinsk-70 in February 1991, the author was astounded by the frankness with which the institute's leadership and specialists discussed the environmental disasters in the Chelyabinsk region. Environmental cooperation is one of the areas they pressed for from the beginning. The overall U.S. response has been disappointing to date.

[56] Significant efforts have been sponsored by the U.S. Nuclear Regulatory Commission and the U.S. Department of Energy.

[57] George L. Voelz, "Plutonium and Health: How Great is the Risk?" *Los Alamos Science* 26 (2000), p. 74.

[58] Condoleezza Rice, "Exercising Power without Arrogance," *Chicago Tribune,* December 31, 2000.

Appendix 1: Summary of Policy Options

HIERARCHY OF RISKS	Ally scenario	Status quo scenario	Reemerging adversary scenario
AVOIDING A NUCLEAR EXCHANGE			
Military cooperation to avoid inadvertent use	Enhanced military and technical cooperation	Enhanced military and technical cooperation	Enhanced military and technical cooperation, if possible
Weapons safety and security exchange	Enhance with targeted program in U.S. interest	Continue but focus on a few areas	Limited exchange advisable, but unlikely
Stockpile stewardship technical cooperation	Enhance in areas in U.S. interest	Focus on a few areas	International cooperation only
Joint test site collaboration	Technical cooperation with joint activities	Information exchange	Limited information exchange, if possible
Cooperation on nuclear accident and emergency response	Enhance with joint center and exercises	Deepen discussions, explore limited joint work	Limited or no cooperation
PREVENTING THEFT OR DIVERSION OF NUCLEAR WEAPONS AND MATERIALS			
Crash effort to secure the most vulnerable nuclear materials	Strengthen and expedite current activities	Strengthen and expedite	Strengthen, if Russia cooperates
Improve nuclear materials protection and remove weapons-usable nuclear materials in Kazakhstan	Re-engage Russia and expedite	Re-engage Russia and expedite	Expedite without Russia, if necessary
Re-focus MPC&A at military sites including the serial production facilities	Return to partnership approach and expedite	Return to partner-ship approach and expedite	Unlikely to get Russian cooperation
Accelerate MPC&A with the Russian Navy	Expedite	Expedite	Expedite if Russia s Navy remains committed
Re-engineering MPC&A at Russian civilian nuclear sites	Renew Russia s commitment, expedite	Renew Russia s commitment, expedite	Renew Russia s commitment, expedite
Downsize civilian and military nuclear complexes	Get Russia s commitment, expedite	Get Russia s commitment, expedite	Proceed, but unlikely
Explore and remediate non-conventional proliferation threats	Get Russia s commitment, expedite	Get Russia s commitment, expedite	Advisable, but unlikely
Enhance second-line of defense program	Expedite	Continue to provide technical support	Continue to provide technical support
PREVENT AGGRESSIVE NUCLEAR EXPORTS			
Cooperative nuclear power development	New initiative, joint reactor development	More limited joint reactor development	Explore, but no financial support
Back-end fuel cycle collaboration	Support spent fuel import, enhance R&D	Consider spent fuel import, support R&D	Explore enhanced collaboration
Joint proliferation risk assessments for nuclear power and fuel cycles	New initiative, joint R&D, and analysis	New initiative, joint R&D and analysis	Low-level support
Joint research on proliferation-resistant fuel cycles	Enhance and focus current R&D	Enhance and focus current R&D	Continue at low level
Joint research on reactor safety	Enhance	Enhance	Continue at low level
Joint export control center	Enhance	Enhance	Continue cooperation

Appendix I: Summary of Policy Options

HIERARCHY OF RISKS	Ally scenario	Status quo scenario	Reemerging adversary scenario
PREVENTION OF LEAKAGE OF NUCLEAR WEAPONS KNOW-HOW			
Nuclear cities conversion	100 CEOs initiative, continue ISTC, and IPP directed at sustainability	Focus on downsizing, continue ISTC, and IPP directed at sustainability	Phase out all programs, especially if economy continues to improve
Joint defense conversion study	Renew joint commitment and expedite	Renew joint commitment and expedite	Limited cooperation
Expanded social infrastructure and people exchange programs	Enhance	Enhance	Continue with focus on people exchanges
Expansion of nuclear complex conversion to other sites	New initiative, if other conversion efforts are successful	Explore	Not advised
DOWNSIZE NUCLEAR MATERIALS INVENTORIES AND PRODUCTION CAPACITY			
Accelerated HEU conversion	Expedite, consider more HEU	Expedite, consider more HEU	Continue current program, explore accelerating
Bilateral fissile materials data exchange	Expedite study, expand scope	Expedite study, expand scope	Complete for civilian, unlikely for military
Reconsideration of plutonium disposition strategy	Re-visit strategy, redefine program	Re-visit strategy, current effort as fall-back	Re-visit strategy
Innovative plutonium solutions	New initiative	Explore new initiative	Explore, but unlikely
Revisit core conversion and civilian reprocessing moratorium	Re-direct	Re-direct	Re-visit
Production capacity parity	New initiative	New initiative	Explore, but unlikely
HELP PREVENT NUCLEAR ACCIDENTS AND ENVIRONMENTAL DISASTERS			
Environmental R&D collaboration	Enhance joint R&D program to benefit both	Enhance joint R&D program to benefit both	Joint R&D, limited funding
Collaboration for nuclear accident prevention	Add nuclear weapons and facilities to reactor accident prevention	Add nuclear weapons and facilities to reactor accident prevention	Explore for civilian, unlikely for military
Collaboration on health effects	Enhance database work, develop joint R&D	Enhance database work, develop joint R&D	Enhance database work, develop joint R&D
Nuclear complex cleanup	Support international initiative for sites of greatest global concern	Support international initiative for sites of greatest global concern	Technical support, no financial assistance