Securing the Bomb 2007

MATTHEW BUNN

PROJECT ON MANAGING THE ATOM
BELFER CENTER FOR SCIENCE AND INTERNATIONAL AFFAIRS
JOHN F. KENNEDY SCHOOL OF GOVERNMENT
HARVARD UNIVERSITY

COMMISSIONED BY THE NUCLEAR THREAT INITIATIVE

SEPTEMBER 2007

www.nti.org/securingthebomb

Printed in the United States of America

Project on Managing the Atom
Belfer Center for Science and International Affairs
John F. Kennedy School of Government
Harvard University
79 JFK Street
Cambridge, MA 02138
Fax: (617) 495-8963
Email: atom@harvard.edu
Web: http://www.managingtheatom.org

Nuclear Threat Initiative
1747 Pennsylvania Avenue NW, 7th Floor
Washington, D.C. 20006
Fax: (202) 296-4811
Email: contact@nti.org
Web: http://www.nti.org

A companion website to this report is available at http://www.nti.org/securingthebomb

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EXECUTIVE SUMMARY

Nuclear terrorism remains a real and urgent danger. Terrorists are actively seeking nuclear weapons and the materials to make them. With enough plutonium or highly enriched uranium (HEU), a sophisticated and well-organized terrorist group could potentially make at least a crude nuclear bomb that could incinerate the heart of any major city. Yet the essential ingredients of nuclear weapons exist in over 40 countries, and there are scores of sites that are not secure enough to defeat the capabilities that terrorists and criminals have demonstrated. Improved security for nuclear stockpiles in Russia and elsewhere as well as the disruption of al Qaeda's centrally controlled structure after 9/11 have reduced the risk, but far more remains to be done. Nuclear theft is an ongoing reality, as demonstrated by the stolen HEU seized in Georgia in early 2006.

In the aftermath of a terrorist mushroom cloud over the cinders of a major city, America and the world would be changed forever. The economic and foreign policy repercussions would be global, potentially pushing millions into poverty. Nor is the United States the only possible target: al Qaeda-linked or inspired attacks intended to cause mass casualties have occurred throughout the world. In short, this is not just an American problem: insecure nuclear material anywhere is a threat to everyone, everywhere.

With sufficient and sustained leadership, the probability of such a catastrophe could be reduced to a small fraction of its current level by the end of the next U.S. presidential term. Every presidential candidate should be asked a central question: what is your plan to prevent terrorists from incinerating the heart of a U.S. city with a nuclear bomb? That risk can never be reduced to zero, but the goal must be to get as close to zero as possible, as quickly as possible.

Keeping nuclear weapons or materials from being stolen is the most direct and reliable tool for preventing nuclear terrorism, for once such items have disappeared, the problem of finding them or stopping terrorists from using them multiplies enormously. The myriad routes across the world's scantily protected borders make nuclear smuggling almost impossible to stop.

Remarkably, it appears that neither the U.S. government nor the International Atomic Energy Agency (IAEA) has a comprehensive, prioritized list assessing which facilities around the world pose the most serious risks of nuclear theft. Such a list would integrate assessments of the quantity and quality of material at each site, the security at that site, and the level of capability adversaries could bring to bear for an attempted theft at that site. Such a prioritized assessment should be prepared urgently, and updated regularly. Based on the limited publicly available data on these factors, it appears that the highest risks of nuclear theft today are in Russia, Pakistan, and at HEU-fueled research reactors.

Nuclear security in Russia has improved dramatically since the mid-1990s, as a result of U.S. and international assistance, Russia's own efforts, and Russia's newfound economic strength. But real risks remain, from persistent under-funding of

nuclear security systems, weak nuclear security regulations, widespread corruption, and conscript guard forces rife with hazing and suicide, coupled with threats ranging from surprise attack by scores of heavily armed terrorists to sophisticated insider theft conspiracies. Russia has the world's largest stockpile of nuclear weapons and materials, and remains the only state in the world where authorities have confirmed that terrorists have been carrying out reconnaissance at nuclear warhead storage sites. Pakistan's nuclear stockpiles are comparatively small, and are believed to be heavily guarded, but face huge threats from armed jihadi groups and nuclear insiders with a demonstrated willingness to sell sensitive nuclear technology. More than 140 research reactors around the world are still fueled by HEU (though usually in forms that would require modest chemical processing before the material could be used in a bomb), and many of these facilities have modest security in place—no more than a night watchman and a chain-link fence in some cases.

Beyond these three highest priorities, other nuclear theft risks exist around the world, from large-scale transports of civilian plutonium to nuclear stockpiles in developing states such as China and India. Every nuclear weapon and every significant cache of potential bomb material, wherever it is in the world, civilian or military, should at least be protected against a modest group of well-trained, well-armed outside attackers (capable of operating in more than one team), one to two well-placed insiders, or both together; in many countries, the plausible threats are greater, and security for such stocks should be correspondingly higher. This is a global problem, which can only be solved through a global campaign for nuclear security.

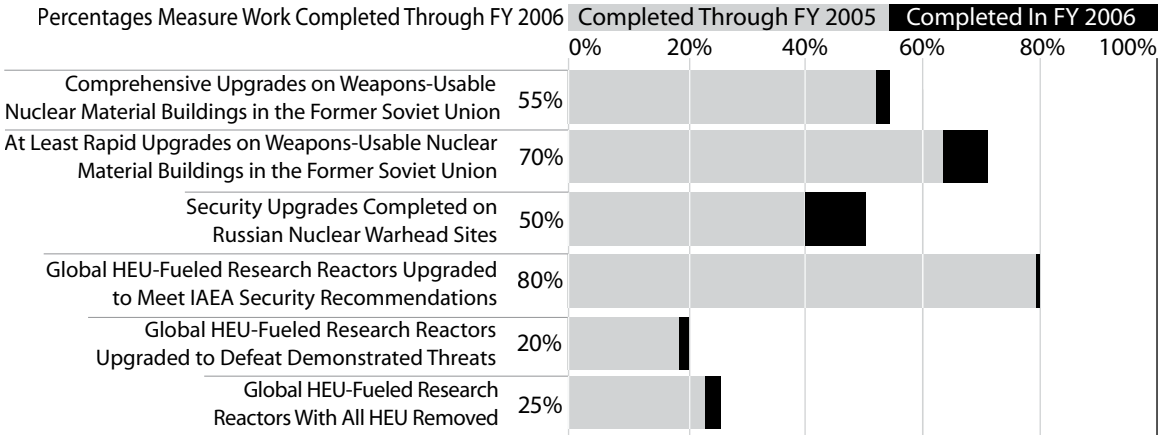
Conceivably, terrorists might get nuclear material or a nuclear weapon consciously provided by a state, rather than stolen weapons or material. But this is likely to be a small fraction of the overall risk of nuclear terrorism. A dictator or oligarch bent on maintaining power is highly unlikely to take the immense risk of transferring such a devastating capability to terrorists they cannot control, given the ever-present possibility that the material would be traced back to its origin.

Assessing Progress in Improving Nuclear Security

Since the 1990s, Nunn-Lugar and related cooperative threat reduction programs have drastically reduced the risks posed by some of the world's highest-risk nuclear stockpiles, providing a benefit for U.S. and world security far beyond their cost—and demonstrating what can be done to address these threats. The past year was one of significant progress, but also one of continuing obstacles and new reminders of the deadly risk of nuclear terrorism—such as the leader of al Qaeda in Iraq calling on nuclear scientists to join the jihad.

By the end of fiscal year (FY) 2006, comprehensive U.S.-funded security and accounting upgrades had been completed for an estimated 55% of all the buildings with weapons-usable nuclear material in the former Soviet Union (63%, if only the buildings where the two sides have agreed on cooperative upgrades are counted). Security upgrades were completed at roughly half of the nuclear warhead sites in Russia (64% if only those sites on the agreed upgrade list are counted). Rapid upgrades (the first stage of upgrades the Department of Energy [DOE] performs at most buildings) had been completed for an additional 15% of the total number of buildings with

Figure ES-1:
Progress of U.S.-Funded Programs to Secure Nuclear Stockpiles



Source: Author's estimates.

weapons-usable material in Russia (18%, if only those buildings the two sides have agreed to upgrade are included), for a total of 70% with at least rapid upgrades in place. See Figure ES-1 (These estimates and the methodology behind them are explained in Chapter 2; they differ from the government figures because they include buildings and facilities in addition to those covered in current plans.) While meeting the current deadline at the end of 2008 for completing these upgrades remains a major challenge, it appears likely that the agreed upgrades will either be completed in 2008 or in the year or two thereafter. The United States and Russia, however, have never agreed to cooperate on a significant number of nuclear material buildings believed to contain large quantities of nuclear material, or on some of Russia's nuclear warhead sites (especially temporary sites). Less than a hundredth of one percent of Russia's vast stockpile of weapons-usable nuclear materials would be enough for several terrorist nuclear bombs, highlighting the need for airtight security throughout Russia's nuclear complex.

With the agreed upgrades nearing completion, the most important policy questions now focus on more intangible, difficult-to-measure factors: Are sufficient security measures being put in place, given the scope of the outsider and insider threats in Russia? Will effective security be sustained over time, after U.S. assistance phases out? Will security cultures at all of these sites be strong enough to ensure that the equipment will actually be used in a way that provides effective security, and guards will not be turning off intrusion detectors or staff propping open security doors? The sustainability agreement that DOE and Russia's Federal Agency for Atomic Energy (Rosatom) reached in April 2007 is a major step forward, and there is significant progress on security culture as well—but both sustainability and security culture remain major challenges, not only at Rosatom sites but at non-Rosatom nuclear material sites and nuclear warhead sites as well.

Outside of the former Soviet Union, nuclear security improvement efforts are still in their early stages, and significant gaps remain. The United States and other countries have provided assistance to upgrade security for more than three-quarters of the world's HEU-fueled research reactors whose physical protection did not match IAEA recommendations, but only a small fraction

of these have been upgraded to levels designed to defeat demonstrated terrorist and criminal threats. See Figure ES-1 U.S. nuclear security cooperation with Pakistan is underway, but Pakistan has made it clear that it will not allow actual U.S. visits to its sensitive nuclear sites, and what precisely has been accomplished in this cooperation remains a secret. In China, one civilian site with HEU has had extensive security and accounting upgrades, and a broad dialogue is underway regarding a range of security and accounting measures, but it remains unclear how much effect this dialogue has had on improving security for other Chinese facilities, and cooperation on military stockpiles remains stymied. Nuclear security cooperation was not included in the summit pact on nuclear cooperation with India, and India has so far refused any cooperation in this area.

Efforts to remove nuclear material from potentially vulnerable sites and to convert research reactors to use non-weapons-usable low-enriched uranium (LEU) as their fuel have accelerated since the establishment of the Global Threat Reduction Initiative (GTRI) in 2004. Moreover, in the last year, GTRI expanded the list of reactors it hopes to convert. But only a small fraction of the HEU-fueled research reactor sites around the world have yet had all their HEU removed. See Figure ES-1 Even with its expanded scope, however, the conversion effort will only cover about half of the world's currently operating HEU-fueled reactors (many of the rest being quite difficult to convert), and some of the conversions GTRI does plan are not slated to occur until 2018. Large amounts of weapons-usable nuclear material are also not yet being addressed. For example, only 5.2 tons of the 17 tons of U.S.-origin HEU abroad is covered by the current U.S. offer to take it back, and currently GTRI only plans to take back about a third of the eligible material (though GTRI does plan to address almost a ton of additional U.S.-origin HEU in its "gap" material program). Some of the material not covered is being reprocessed or otherwise addressed abroad, and some of it is at sites with highly effective security—but some of it is not.

The Global Initiative to Combat Nuclear Terrorism, launched in July 2006, has the potential to be an important tool for convincing governments around the world that nuclear terrorism is a real and urgent threat, and for focusing them on specific actions they can take to reduce the risk. The key challenges now are to move from the extremely general principles the participants have accepted to concrete actions to improve nuclear security—including agreement on effective standards for nuclear security that all participants would agree to maintain.

Next Steps in Nuclear Security

The danger of nuclear theft and terrorism is a global problem, requiring a global response. While much has been accomplished, much more remains to be done to prevent a nuclear 9/11.

A Global Campaign to Prevent Nuclear Terrorism

President Bush, working with other world leaders, should launch a global campaign to lock down every nuclear weapon and every significant cache of potential nuclear bomb material worldwide, as rapidly as that can possibly be done—and to take other key steps to reduce the risk of nuclear terrorism. This effort must be at the center of U.S. national security policy and diplomacy—an issue to be raised with every country with stockpiles to secure or resources to help, at every level, at every opportunity, until the job is done.

This campaign should creatively and flexibly integrate a broad range of policy tools to achieve the objective—from technical experts cooperating to install improved security systems at particular sites to presidents and prime ministers meeting to overcome obstacles to cooperation. The recently launched Global Initiative to Combat Nuclear Terrorism may provide the best forum to pursue some of these goals. For other goals, high-level bilateral initiatives such as the nuclear security agreement reached between President Bush and President Putin in 2005 may offer the most effective approach. For still other efforts, cooperation led by international organizations such as the IAEA may be the forum that other countries most readily accept. The United States should do everything possible to work with states such as Russia and Pakistan to ensure that their stockpiles are sustainably secured against all of the outsider and insider threats terrorists and criminals could plausibly bring to bear; those efforts should be seen as key parts of this broader global campaign. Such a campaign should also include expanding the mission, personnel, and funding of the IAEA's Office of Nuclear Security, as there are many steps the widely-respected international organization can take more effectively than the United States can unilaterally.

To succeed, this campaign should be based not just on donor-recipient relationships but on real partnerships, which integrate ideas and resources from countries where upgrades are taking place in ways that also serve their national interests. For countries like India and Pakistan, for example, the opportunity to join with the major nuclear states in jointly addressing a global problem is more politically appealing than portraying the work as U.S. assistance necessitated because they are unable to adequately control their nuclear stockpiles on their own. It is essential to pursue approaches that make it possible to cooperate in upgrading nuclear security without demanding that countries compromise their legitimate nuclear secrets. Specific approaches should be crafted to accommodate each national culture, secrecy system, and set of circumstances.

The fundamental key to the success of such a campaign is convincing political leaders and nuclear managers around the world that nuclear terrorism is a real and urgent threat to *their* countries' security, worthy of a substantial investment of their time and money to reduce the danger. If they are convinced, they will take the actions necessary to achieve effective and lasting security for their nuclear stockpiles; if they are not, they will not take the political risks of opening sensitive sites to nuclear security cooperation, give their nuclear regulators the mission and power to enforce effective nuclear security rules, or provide the resources necessary to sustain high levels of security. The United States and other countries should take several steps to build the needed sense of urgency and commitment, including:

- **Joint threat briefings.** Upcoming summits with political leaders of key countries should include detailed briefings for both leaders on the nuclear terrorism threat, given jointly by U.S. experts and experts from the country concerned. These would outline both the very real possibility that terrorists could get nuclear material and make a nuclear bomb, and the global economic and political effects of a terrorist nuclear attack.

- **Nuclear terrorism exercises.** The United States and other leading countries should organize a series of exercises with senior policymakers from key states, with scenarios tailored to the circumstances of each country or

region where the exercises take place. Participating in such a simulation can reach officials emotionally in a way that briefings and policy memos cannot.

- **Fast-paced nuclear security reviews.** The United States and other leading countries should encourage leaders of key states to pick teams of security experts they trust to conduct fast-paced reviews of nuclear security in their countries, assessing whether facilities are adequately protected against a set of clearly-defined threats. (In the United States, such fast-paced reviews after major incidents such as 9/11 have often revealed a wide range of vulnerabilities that needed to be fixed.)

- **Realistic testing of nuclear security performance.** The United States and other leading countries should work with key states around the world to implement programs to conduct realistic tests of nuclear security systems' ability to defeat either insiders or outsiders. (Failures in such tests can be powerful evidence to senior policymakers that nuclear security needs improvement.)

- **Shared databases of threats and incidents.** The United States and other key countries should collaborate to create shared databases of unclassified information on actual security incidents (both at nuclear sites and at non-nuclear guarded facilities) that highlight the kinds of capabilities, tactics, and weaponry thieves and terrorists have used. Such a database would not only help convince policymakers and facility managers of the reality of the threats their facilities face; it would also help them determine what design basis threats nuclear facilities should be protected against and help them draw lessons that could prevent similar adversary actions at their facilities.

Effective Global Nuclear Security Standards

As part of this global campaign, President Bush and other leaders of major nuclear weapon and nuclear energy states should immediately seek agreement on a broad political commitment to meet at least a common minimum standard of nuclear security. Effective global standards are urgently needed, for in the face of terrorists with global reach, nuclear security is only as good as its weakest link. The standard should be rigorous enough that all stockpiles with such security measures are well protected against plausible insider and outsider threats, but flexible enough to allow each country to take its own approach to nuclear security and to protect its nuclear secrets. For example, the agreed global standard might be that all nuclear weapons and significant caches of weapons-usable nuclear materials be protected at least against two small groups of well-armed and well-trained outsiders, one to two well-placed insiders, or both outsiders and insiders working together. Where countries believe bigger threats are possible, they should provide greater protection.

United Nations Security Council Resolution 1540, which legally requires all states to provide "appropriate effective" security and accounting for any nuclear stockpiles they may have, provides an excellent opportunity, as yet unused, to back up such a high-level political commitment. If the words "appropriate effective" mean anything, they should mean that nuclear security systems could effectively defeat threats that terrorists and criminals have demonstrated.

Hence, the United States should seek the broadest possible agreement that UNSCR 1540 already legally binds states to meet a minimum level of nuclear security com-

parable to the one just described. The United States should immediately begin working with the other Global Initiative participants and the IAEA to detail the essential elements of an "appropriate effective" system for nuclear security, to assess what improvements countries around the world need to make to put these essential elements in place, and to assist countries in taking the needed actions. The United States should also begin discussions with key nuclear states to develop the means to build international confidence that states have fulfilled their commitments to take effective nuclear security measures, without unduly compromising nuclear secrets.

International discussions of a new revision to the IAEA's physical protection recommendations are just beginning. The United States should seek agreement that the revised text recommend that all states require facilities with the most sensitive materials to be effectively protected against a minimum threat like that described above.

A "security Chernobyl" resulting from a successful sabotage of a nuclear plant or a nuclear theft leading to nuclear terrorism would be both a human catastrophe and a disaster for the global nuclear industry, ending any plausible chance for a large-scale nuclear renaissance. Hence, complementing government efforts, the nuclear industry should launch its own initiative focused on bringing the worst security performers up to the level of the best performers, through defining and exchanging best practices, industry peer reviews, and similar measures—a World Institute for Nuclear Security (WINS) on the model of the World Association of Nuclear Operators (WANO) established to improve global nuclear safety after the Chernobyl accident. The Nuclear Threat Initiative (NTI) has taken the lead in launching such an organization, working with the Institute for Nuclear Materials Management (INMM) and other stakeholders. Both governments and the nuclear industry should strongly support this effort, which can help engage nuclear operators themselves in the pursuit of excellence in nuclear security.

Building Sustainability and Strong Security Cultures

If the nuclear security and accounting equipment is broken or unused five years after its installation by the U.S. or other countries, or if guards are turning off intrusion detectors and staff are propping open security doors for convenience, efforts to drastically reduce the danger of nuclear theft and terrorism will fail. Hence, ensuring that high levels of security will be sustained for the long haul, and forging strong security cultures, where all relevant staff put high priority on security, are absolutely critical to success.

Here again, convincing foreign leaders and nuclear managers of the reality and urgency of the threat is the most important ingredient of success; unless they are convinced that nuclear security is essential to their own security, they are unlikely to take the actions needed to sustain high levels of security, or to build strong security cultures.

Building on the recent DOE-Rosatom agreement on sustainability, the United States and other leading states should be working with countries around the world to put in place the *resources*, *organizations*, and *incentives* that are required to sustain effective nuclear security for the long haul. In particular:

- The United States should seek a presidential-level commitment from Russia

to provide sufficient money and capable people to sustain effective nuclear security and accounting at all facilities (and transport operations) with nuclear weapons or weapons-usable nuclear materials. (The United States should make clear that it is committed to doing the same for its own nuclear stockpiles.) Ultimately other countries where upgrades are taking place should make similar commitments as well.

- The United States and other leading states should seek to ensure that every facility and transport operation with nuclear weapons or weapons-usable material worldwide has all that is needed to sustain effective nuclear security, including the necessary procedures, training, and maintenance arrangements. In particular every facility and transport operation with nuclear weapons or weapons-usable nuclear material worldwide should have an organization focused on nuclear security and accounting, and these organizations should have the needed resources, expertise, and authority. The ministries, agencies, or companies that control these facilities and transport operations should also have appropriate organizations in place to focus on sustaining effective nuclear security.

- The United States and other leading states should seek to ensure that every country with nuclear weapons or weapons-usable nuclear materials has effective nuclear security and accounting rules, effectively enforced. Most nuclear managers will only invest in the expensive nuclear security measures the government requires—so nuclear security regulation is central to effective and lasting nuclear security.

- The United States and other leading states should take additional steps to ensure that states and facilities have strong incentives to provide effective nuclear security, including establishing preferences in all contracts for facilities that have demonstrated superior nuclear security performance.

At the same time, the United States and other leading states should do everything possible to build strong security cultures for all organizations involved with managing nuclear weapons and weapons-usable nuclear materials. Organizational cultures start from the top, so it is essential to convince nuclear managers to build cultures focused on high security. This requires, at a minimum: intensive training on the threat; coordinators in each organization whose job is developing security culture awareness; and incentives for strong security performance. Here, too, realistic performance testing and other kinds of simulations and exercises can help convince guards and staff of the reality of the threat and what needs to be done to defend against it, and shared databases of confirmed security incidents can educate security personnel about the threats that exist. Both the nuclear industry as well as other industries have broad experience in building strong safety cultures in high-risk organizations; all countries with nuclear weapons or weapons-usable nuclear material should take steps to strengthen security culture that build on that experience. Organizational cultures are difficult to regulate—though some regulators seek to do so, requiring organizations to launch improvement programs when inspections suggest a cultural problem—but implementation of best practices and lessons learned from past problems and incidents, which are indicators of security culture, can and should be regulated.

An Accelerated and Expanded Global Cleanout

The only foolproof way to ensure that nuclear material will not be stolen from a particular site is to remove it. As a central part of the global campaign to prevent nuclear terrorism, the United States should immediately begin working with other countries to take steps to accelerate and expand the removal of weapons-usable nuclear material from vulnerable sites around the world. Where material cannot immediately be removed, the United States must speed steps to ensure that high levels of security are implemented and maintained. The goal should be to remove all nuclear material from the world's most vulnerable sites within four years—substantially upgrading security wherever that cannot be accomplished—and to eliminate all HEU from civil sites worldwide within roughly a decade. That is a challenging goal, but potentially achievable with sustained high-level leadership. The United States should make every effort to build international consensus that the civilian use of HEU is no longer acceptable, that all HEU should be removed from all civilian sites, and that all civilian commerce in HEU should be ended as quickly as possible.

Achieving these goals will require a strengthened, broadened effort, including:

- **Incentives.** The United States and other leading countries should provide substantial packages of incentives, targeted to the needs of each facility and host country, to convince research reactors to convert from HEU to low-enriched uranium or to shut down and to convince these and related sites to ship their HEU elsewhere for secure storage and disposition.

- **Shut-down as an additional policy tool**. To date, U.S. efforts to reduce the use of HEU at potentially vulnerable research reactors have focused only on conversion to LEU. Many research reactors, however, are difficult to convert, and many more are underutilized and no longer offer benefits that justify their costs and risks. For these, the cheaper and quicker answer is likely to be to provide incentives to help convince reactors to shut down—including arrangements to support their scientists doing research as user groups at other facilities. To maintain the trust needed to convince reactor operators to convert to LEU, however, any shut-down effort should be institutionally separate from the conversion effort—perhaps under the rubric of a "Sound Nuclear Science Initiative" focused on ensuring that the world gets the highest-quality research, training, and isotope production out of the smallest number of safe and secure reactors at the lowest cost. This could include enhancing the research capabilities of certain reactors that could serve as regional centers of excellence, and investments in alternative scientific projects that do not require research reactors.

- **An expanded set of reactors.** While the Global Threat Reduction Initiative has expanded its scope to include 129 research reactors they would like to convert (48 of which were already converted or shut down by the end of 2006), roughly half of the research reactors operating with HEU around the world today are still not covered by the conversion effort. But with an expanded set of tools—including shut-down in addition to conversion—many of these difficult-to-convert reactors can and should be addressed. To remove threats inside U.S. borders and enable American leadership in convincing others to do the same, the United States should also convert or shut down its own HEU-fueled research reactors, and

implement effective nuclear security measures to protect them while HEU is still present.

- **An expanded set of material.** The United States and other leading states should greatly expand and accelerate their programs to take back or otherwise arrange for the disposition of potentially vulnerable HEU and separated plutonium around the world. The focus should be on whether the particular stock poses a security risk, not whether it fits within the stovepipe of a particular program. The goal should be to remove all potential bomb material from sites that cannot easily be effectively secured as rapidly as possible, and to reduce the total number of sites where such material exists to the lowest practicable number. The United States should expand its own take-back offer to cover *all* stockpiles of U.S.-supplied HEU, except for cases in which a rigorous security analysis demonstrates that little if any risk of nuclear theft exists; on a case-by-case basis, the United States should also accept other weapons-usable nuclear material that poses a proliferation threat. The United States should seek agreement from Russia, Britain, France, and other countries to receive and manage high-risk materials when the occasion demands, to share the burden. The United States should also seek to eliminate vulnerable stocks of separated civilian plutonium where practicable, should renew the effort to negotiate a 20-year U.S.-Russian moratorium on separating weapons-usable plutonium, and should work to ensure that its reconsideration of modified approaches to reprocessing in the Global Nuclear Energy Partnership does not encourage the spread of plutonium separation facilities.

Beyond Nuclear Security

While upgrading nuclear security and removing nuclear weapons and weapons-usable nuclear materials from vulnerable sites are the most important measures that can be taken to reduce the risk of nuclear terrorism, the United States and other leading states should pursue a layered defense that includes a range of other approaches as well.

- **Disrupt.** Counterterrorist measures focused on detecting and disrupting those groups with the skills and ambitions to attempt nuclear terrorism should be greatly strengthened. New steps should be taken to make recruiting nuclear experts and technicians more difficult (including addressing some of the sources of radical Islamic violence and hatred, and challenging the moral legitimacy of mass-casualty terror within the Islamic community).

- **Interdict.** A broad system of measures to detect and disrupt nuclear smuggling and terrorist nuclear bomb efforts should be put in place, including not only radiation detectors but also increased emphasis on intelligence operations such as supply and demand "stings" (that is, intelligence agents posing as buyers or sellers of nuclear material or nuclear expertise), and targeted efforts to encourage participants in such conspiracies to blow the whistle. Success will require a substantial expansion of international intelligence cooperation and information-sharing related to nuclear trafficking. Given the stakes, nations around the world should pass and enforce laws that make trafficking in potential nuclear bomb material a crime comparable to murder or treason.

- **Prevent and deter.** The international community must convince North Ko-

rea and Iran to verifiably end their nuclear weapons efforts (and, in North Korea's case, to give up the weapons and materials already produced). At the same time, the global effort to stem the spread of nuclear weapons should be significantly strengthened, reducing the chances that a state might provide nuclear materials to terrorists (though conscious decisions by states to give nuclear weapons or weapons-usable material to terrorists are already a less likely path for terrorists to get the bomb than nuclear theft). The United States should also put in place the best practicable means for identifying the source of any nuclear attack—including not just nuclear forensics but also traditional intelligence means—and announce that the United States will treat any terrorist nuclear attack using material consciously provided by a state as an attack by that state, and will respond accordingly.

Getting the Job Done

None of these initiatives will be easy. A maze of political and bureaucratic obstacles must be overcome—quickly—if the world's most vulnerable nuclear stockpiles are to be secured before terrorists and thieves get to them. While President Bush has rightly said that preventing nuclear terrorism must be the nation's top priority, he has focused only intermittently on international cooperation to improve nuclear security, the most potent available tool to reduce the risk. The substantial results when he has—such as the acceleration of work following the Bush-Putin nuclear security summit accord at Bratislava in 2005—hint at what could be accomplished with sustained push from the Oval Office.

To ensure that this work gets the priority it deserves, President Bush should appoint a senior full-time White House official, with the access needed to walk in and ask for presidential action when needed, to lead these efforts and to keep them on the front burner at the White House every day. That official would be responsible for finding and fixing the bureaucratic and other obstacles to progress in the scores of existing U.S. programs scattered across several cabinet departments of the U.S. government that are focused on pieces of the job of keeping nuclear weapons out of terrorist hands—and for setting priorities, eliminating overlaps, and seizing opportunities for synergy.

That full-time leader should be charged with preparing an integrated and prioritized plan for the many steps needed to reduce the risk of nuclear terrorism. Of course, that plan will have to be adapted and modified as obstacles and opportunities change. The President and the Congress should ensure that sufficient resources are provided so that none of the key efforts focused on reducing this risk are slowed down by a lack of funds. And President Bush should direct the intelligence community to give top priority, working with the policy and implementation agencies, to collecting the information needed to focus this effort, ranging from assessments of the level of security in place at nuclear facilities around the world, to morale and corruption among guards and staff.

In short, with so many efforts under way tackling different pieces of the nuclear terrorism problem, it is time—in the United States, in Russia, and in other leading countries around the world—to put in place a single leader for the effort, an integrated plan, and the resources and information needed to carry out the plan.

1 PREVENTING THE CATASTROPHE OF NUCLEAR TERRORISM

Every candidate for president in 2008 should be asked a fundamental question: what is your plan to prevent terrorists from incinerating the heart of a U.S. city with a nuclear bomb?

Today, unfortunately, a terrorist nuclear attack is a very real danger. During the 2004 campaign, President Bush and Senator John Kerry agreed that nuclear terrorism was the greatest current danger to U.S. national security. That conclusion remains valid. Improved security for nuclear stockpiles in Russia and elsewhere and the disruption of al Qaeda's centrally controlled structure after 9/11 have reduced the risk, but far more remains to be done.

With sufficient sustained leadership, the probability of such a catastrophe could be reduced to a small fraction of its current level by the end of the next U.S. presidential term. While the probability that terrorists could get and use a nuclear bomb can never be reduced to zero, the goal must be to get as close to zero as possible, as quickly as possible.

To achieve such a drastic reduction in the risk of nuclear terrorism will require a comprehensive strategy including several key steps:

- **Secure.** Every nuclear weapon and every significant cache of potential nuclear bomb material worldwide should be sustainably secured and accounted for, to standards sufficient to defeat the threats that terrorists and criminals have shown they can pose.
- **Remove.** Potential nuclear bomb material should be removed entirely from the world's most vulnerable, difficult-to-defend sites, and the total number of buildings and bunkers worldwide where nuclear weapons or nuclear bomb material exists should be cut by half or more.
- **Disrupt.** Counterterrorist measures focused on detecting and disrupting those groups with the skills and ambitions to attempt nuclear terrorism should be greatly strengthened, and new steps should be taken to make recruiting nuclear experts more difficult (including addressing some of sources of radical Islamic violence and hatred, and challenging the moral legitimacy of mass-casualty terror within the Islamic community).
- **Interdict.** A broad system of measures to detect and disrupt nuclear smuggling and terrorist nuclear bomb efforts should be put in place, including not only radiation detectors but also increased emphasis on intelligence operations such as supply and demand "stings" (that is, intelligence agents posing as buyers or sellers of nuclear material or nuclear expertise), and targeted efforts to encourage participants in such conspiracies to blow the whistle.
- **Prevent and deter.** New steps should be taken to convince North Korea and Iran to verifiably abandon their nuclear weapons programs, and the global effort to stem the spread of nuclear weapons should be significantly strengthened, thus reducing the chances that a state might provide nu-

clear materials to terrorists. The United States should put in place the best practicable means for identifying the source of any nuclear attack—including not just nuclear forensics but traditional intelligence means as well—and make very clear that the United States will treat any terrorist nuclear attack using material provided by a state as an attack by that state, and will respond accordingly.

This report offers a road map for a drastic reduction in the danger of nuclear terrorism.[1] It focuses primarily on the first two of these steps, for they offer the greatest leverage in reducing the risk that terrorists will get and use a nuclear bomb. The complexities of producing nuclear bomb materials from scratch are beyond the plausible capabilities of terrorist groups. Hence, if all the stockpiles produced by states can be reliably kept out of terrorist hands, nuclear terrorism can be reliably prevented. But once nuclear material has been stolen, it could be anywhere, and all the subsequent layers of defense, unfortunately, are variations on looking for needles in haystacks.

[1] This report addresses only terrorist use of actual nuclear explosives—either nuclear weapons produced by a state that terrorists managed to get and to detonate, or crude nuclear bombs terrorists might succeed in making themselves from plutonium or Highly Enriched Uranium (HEU) they managed to acquire. For a discussion of other nuclear-related types of terrorism, such as sabotage of major nuclear facilities and of dispersal of radioactive material in a so-called "dirty bomb," see, for example, Charles D. Ferguson and William C. Potter, with Amy Sands, Leonard S. Spector, and Fred L. Wehling, *The Four Faces of Nuclear Terrorism*, ed. Amy Sands, Leonard S. Spector, and Fred L. Wehling (Monterey, Cal.: Center for Nonproliferation Studies, Monterey Institute of International Studies, 2004; available at http://www.nti.org/c_press/analysis_4faces.pdf as of 2 January 2007). A substantial literature on the danger of nuclear terrorism is now available. For one comprehensive (and alarming) look, see Graham T. Allison, *Nuclear Terrorism: The Ultimate Preventable Catastrophe*, 1st ed. (New York: Times Books/Henry Holt, 2004).

This report is the sixth in a series. Readers of the previous reports will find much that is familiar, but some that is new. Much has been accomplished to improve security for nuclear stockpiles in the years we have been providing annual assessments of this problem—but much more remains to be done. There remains a dangerous gap between the urgency of the threat and the pace and scale of the U.S. and international response.

The Shape of the Danger

The facts that the frame the danger are stark:

- Terrorist groups are actively seeking stolen nuclear weapons and materials and actively seeking to recruit nuclear expertise.

- With enough of the needed materials in hand—some 50 kilograms (110 pounds) of HEU for the simplest "gun-type" device—terrorists could plausibly build and detonate at least a crude nuclear explosive.

- Tens of thousands of nuclear weapons and enough weapons-usable nuclear material to make hundreds of thousands more exist in the world. These stockpiles are located in hundreds of buildings in dozens of countries.

- Security and accounting arrangements for these nuclear stockpiles range from excellent to appalling, with no binding global security standards in place.

- As a result of these conditions, a substantial number of incidents of actual theft of weapons-usable nuclear material have occurred.

- Smuggling of nuclear weapons or materials is extraordinarily difficult to interdict. Defenses based on detectors

at borders and elsewhere will always be porous.

- Detonation of a terrorist nuclear bomb in a major city would represent a catastrophe of historic proportions.

The next sections will discuss each of these points in turn.

There is good news as well, however. So far, there is no convincing evidence that any terrorist group or proliferating state has yet received a stolen nuclear weapon or stolen weapons-usable nuclear material. Indeed, much of the fragmentary evidence that exists in the public domain suggests al Qaeda has repeatedly been scammed in its efforts to get nuclear bomb material, and that some of their senior operatives have had rudimentary and sometimes incorrect knowledge of nuclear matters.[2] Much the same appears to have been the case for Aum Shinrikyo, the Japanese terror cult that sought nuclear weapons in the 1990s and launched the 1995 nerve gas attack in the Tokyo subways. Unfortunately, it certainly remains plausible that some cell that has not yet been detected has made more progress than the world knows; it is worth remembering that Aum Shinrikyo was unknown to the world's intelligence agencies before its nerve gas was released in Tokyo.

Terrorists Are Seeking Nuclear Weapons

By word and deed, al Qaeda and the global movement it has spawned have made it clear that they want nuclear weapons.[3] Osama bin Laden has called acquiring nuclear weapons a "religious duty."[4] Al Qaeda operatives have repeatedly attempted to obtain nuclear material and recruit nuclear expertise. The U.S. government has formally charged that bin Laden has been seeking nuclear weapons and the materials to make them since the early 1990s[5]—and by 1996, the CIA's bin Laden unit had documented a "professional" nuclear acquisition effort leaving "no doubt that al-Qaeda was in deadly earnest in seeking nuclear weapons."[6]

In August 2001, just weeks before the 9/11 attacks, two senior Pakistani nuclear weapons scientists met with bin Laden and his deputy Ayman al-Zawahiri at length and discussed nuclear weapons, reportedly handing over a rough sketch of a nuclear bomb design, and discussing what other Pakistani scientists could be

[2] Matthew Bunn and Anthony Wier, with Joshua Friedman, "The Demand for Black Market Fissile Material," in *Nuclear Threat Initiative Research Library: Securing the Bomb* (Cambridge, Mass.: Project on Managing the Atom, Harvard University, and Nuclear Threat Initiative, 2005; available at http://www.nti.org/e_research/cnwm/threat/demand.asp as of 2 January 2007).

[3] Bunn and Wier, "The Demand for Black Market Fissile Material."

[4] Rahimullah Yusufzai, "Interview with Bin Laden: World's Most Wanted Terrorist" (ABC News, 1999; available at http://www.islamistwatch.org/blogger/localstories/05-06-03/ABCInterview.html as of 5 January 2007).

[5] "Text: US Grand Jury Indictment against Usama Bin Laden" (New York: United States District Court, Southern District of New York, 6 November 1998; available at http://www.fas.org/irp/news/1998/11/98110602_nlt.html as of 10 July 2007).

[6] Anonymous [Michael Scheuer], "How Not to Catch a Terrorist," *Atlantic Monthly* 294, no. 5 (2004; available at http://www.theatlantic.com/doc/200412/anonymous as of 09 July 2007), p. 50. The 9/11 Commission, in a footnote, refers to a report from the Bin Laden unit on al Qaeda's "efforts to acquire WMD materials" that was published in early 1997; since Scheuer reports that his team's analysis was not distributed until well after it was produced, this is likely the same report. See National Commission on Terrorist Attacks upon the United States, The 9/11 Commission Report: Final Report of the National Commission on Terrorist Attacks Upon the United States, 1st ed. (New York: Norton, 2004; available at http://www.gpoaccess.gov/911/index.html as of 10 July 2007), p. 479, fn. 3.

recruited for the effort.[7] Documents recovered in Afghanistan reveal a significant al Qaeda research effort focused on nuclear weapons—though no proof that this effort was making major progress toward getting the bomb.[8] Long after the removal of al Qaeda's Afghanistan sanctuary, bin Laden sought and received a religious ruling or *fatwa* from a radical Saudi cleric authorizing the use of nuclear weapons against American civilians.[9]

Former Director of Central Intelligence George Tenet, in his memoir, argues that al Qaeda's top leadership remains "singularly focused" on acquiring nuclear, chemical, or biological weapons, and describes himself as convinced that the top al Qaeda leaders "desperately want" a nuclear bomb in particular.[10] Tenet reports that:

- A November 2001 briefing that he and a senior CIA expert on weapons of mass destruction gave President Bush and others on al Qaeda's nuclear efforts and the possibility that senior Pakistani scientists might be aiding them was so alarming that President Bush directed Tenet to fly to Pakistan "the next day"

[7] Peter Baker, "Pakistani Scientist Who Met Bin Laden Failed Polygraphs, Renewing Suspicions," *Washington Post*, 3 March 2002; Kamran Khan, "Pakistan Releases Nuclear Scientists for Ramadan's End," *The Washington Post*, 16 December 2001; Kamran Khan and Molly Moore, "2 Nuclear Experts Briefed Bin Laden, Pakistanis Say," *Washington Post*, 12 December 2001. The report that the Pakistani scientists had provided al Qaeda's leaders with "a hand-drawn rough bomb design" is from George Tenet, *At the Center of the Storm: My Years at the CIA* (New York: HarperCollins, 2007), p. 268. The most thorough available account of the incident and related issues is David Albright and Holly Higgins, "A Bomb for the Ummah," *Bulletin of the Atomic Scientists* 59, no. 2 (March/April 2003; available at http://www.thebulletin.org/issues/2003/ma03/ma03albright.html as of 2 January 2007), pp. 49-55. Ummah is a term for the worldwide Islamic community. Tenet's memoir also some new information about this incident, supplementing Albright and Higgins' account.

[8] For useful accounts of al Qaeda's nuclear efforts, see, for example, David Albright, "Al Qaeda's Nuclear Program: Through the Window of Seized Documents," *Nautilus Institute Special Forum* 47 (2002; available at http://www.nautilus.org/archives/fora/Special-Policy-Forum/47_Albright.html as of 2 January 2007); David Albright, Kathryn Buehler, and Holly Higgins, "Bin Laden and the Bomb," *Bulletin of the Atomic Scientists* 58, no. 1 (January/February 2002; available at http://www.isis-online.org/publications/terrorism/binladenandbomb.pdf as of 2 January 2007), pp. 23-24; Sara Daly, John Parachini, and William Rosenau, *Aum Shinrikyo, Al Qaeda, and the Kinshasa Reactor: Implications of Three Case Studies for Combating Nuclear Terrorism* (Santa Monica, Cal.: RAND, 2005; available at http://www.rand.org/pubs/documented_briefings/2005/RAND_DB458.sum.pdf as of 5 January 2007). For a quick summary of open reporting on al Qaeda's efforts, see Weapons of Mass Destruction Terrorism Research Program, "Chart: Al Qa'ida's WMD Activities" (Monterey, Calif.: Center for Nonproliferation Studies, Monterey Institute of International Studies, 13 May 2005; available at http://cns.miis.edu/pubs/other/sjm_cht.htm as of 09 July 2007). For a useful discussion of the early days of al Qaeda's efforts, see text and sources in Gavin Cameron, "Multitrack Microproliferation: Lessons from Aum Shinrikyo and Al Qaeda," *Studies in Conflict and Terrorism* 22, no. 4 (October-December 1999).

[9] See Nasr bin Hamd al-Fahd, "A Treatise on the Legal Status of Using Weapons of Mass Destruction Against Infidels," originally released on jihadist web sites in May 2003. A full translated text was available as of 10 September 2007 at http://www.carnegieendowment.org/static/npp/fatwa.pdf. For an analysis of this fatwa (which also includes a modestly different translation of major portions of it) see Reuven Paz, Project for the Research of Islamist Movements (PRISM), "Yes to WMD: The first Islamist Fatwah on the use of Weapons of Mass Destruction," PRISM Special Dispatches 1, no. 1 (May 2003). Al-Fahd was subsequently arrested in Saudi Arabia, and publicly renounced some of his previous rulings, though whether this one is among them is not clear.

[10] Tenet, *At the Center of the Storm*, p. 279. Some of Tenet's claims regarding the CIA's role in the lead-up to the Iraq war have been extensively challenged, and independent confirmation of his accounts of these events relating to al Qaeda's nuclear efforts is not available. It seems reasonable to believe, however, that the discussions of this topic with U.S. and foreign leaders that Tenet describes did occur — though other participants in these discussions may remember their key points somewhat differently.

to convince President Pervez Musharraf to take action.[11]

- In 2002 and 2003, long after the disruption of al Qaeda's central command structure in Afghanistan, the CIA received "a stream of reliable reporting" that al Qaeda was negotiating to purchase three Russian nuclear weapons—reports that were sufficiently detailed and that Tenet was directed to personally call then-Russian Minister of Defense Sergei Ivanov, and dispatch the CIA's top expert on nuclear, chemical, and biological weapons to Moscow to seek cooperation from Russian intelligence.[12]

Al Qaeda's nuclear ambitions appear to continue to the present day. In September 2006, an audiotape in which the speaker identified himself as Abu Hamza al-Muhajir, the head of al Qaeda in Iraq (also known as Abu Ayyub al-Masri) called on experts in "chemistry, physics, electronics, media and all other sciences, especially nuclear scientists and explosives experts" to join the jihad. "The field of jihad can satisfy your scientific ambitions," he said, and "the large American bases (in Iraq) are good places to test your unconventional weapons, whether biological or dirty, as they call them."[13]

Nor is al Qaeda the only terrorist group that has pursued nuclear weapons. As noted earlier, in the 1990s the Japanese terror cult Aum Shinrikyo also launched a significant effort to get a nuclear bomb, which, like al Qaeda's effort, included attempting to buy stolen nuclear warheads or nuclear material from the former Soviet Union (though much of the group's nuclear effort was poorly focused).[14] In Russia, Chechen terrorists (some of whom have close links to al Qaeda) have carried out reconnaissance at nuclear weapon storage sites,[15] and the Russian Minister of the Interior, in charge of the troops who guard most nuclear facilities, has warned that "international terrorists have planned attacks against nuclear and power industry installations...to seize nuclear materials and use them to build weapons of mass destruction."[16]

[11] Tenet, *At the Center of the Storm*, pp. 264-268. A similar account of this meeting with Musharraf—possibly also based on Tenet as the principal source-can be found in Ron Suskind, *The One Percent Doctrine: Deep Inside America's Pursuit of Its Enemies Since 9/11* (New York: Simon and Schuster, 2006), pp. 61-69.

[12] Tenet, *At the Center of the Storm*, pp. 275-276. Tenet reports that this meeting did not lead to a breakthrough in intelligence cooperation, which, he says, will require "a fundamental shift in policy." One might add that a real intelligence partnership to tackle this issue is critically important, but will likely require such shifts in both Moscow and Washington Tenet also claims that one senior al Qaeda operative told investigators that al Qaeda's nuclear weapons effort had reached the point of carrying out tests of conventional explosives for eventual use in a nuclear device (p. 275). It is difficult to evaluate the importance of this report without confirmation and more detail. If such tests were carried out, and were sufficiently advanced to prepare al Qaeda for making a nuclear bomb once it acquired nuclear material and was able to form it into appropriate shapes, this would be a critical piece of information. It is also possible, however, that such tests did not occur, or were so primitive that they gave al Qaeda little additional confidence that it could make a bomb.

[13] David Rising, "Iraq Terrorist Calls Scientists to Jihad," *Associated Press Newswires*, 28 September 2006. This statement reinforces the importance of U.S. and international efforts (sponsored by both DOE and the Department of State) to engage and reemploy weapons scientists in Iraq and elsewhere, to try to keep them from being tempted by well-paid offers to contribute to terrorist weapons programs or those of proliferating states..

[14] Bunn and Wier, "The Demand for Black Market Fissile Material."

[15] This has been confirmed by the commander of the forces that guard Russia's nuclear weapon storage facilities. See, for example, "Russia: Terror Groups Scoped Nuke Site," *Associated Press*, 25 October 2001; Pavel Koryashkin, "Russian Nuclear Ammunition Depots Well Protected—Official," *ITAR-TASS*, 25 October 2001.

[16] "Internal Troops to Make Russian State Facilities Less Vulnerable to Terrorists," *RIA-Novosti*, 5 Octo-

With Material, Terrorists Could Plausibly Make Nuclear Weapons

If terrorists could obtain the HEU or plutonium that are the essential ingredients of a nuclear bomb, making at least a crude nuclear bomb might well be within the capabilities of a sophisticated group.[17] One study by the now-defunct congressional Office of Technology Assessment summarized the threat: "A small group of people, none of whom have ever had access to the classified literature, could possibly design and build a crude nuclear explosive device... Only modest machine-shop facilities that could be contracted for without arousing suspicion would be required."[18]

The simplest type of nuclear bomb for terrorists to build would be a so-called "gun-type" bomb, which involves little more than slamming two pieces of HEU together at high speed. The bomb that incinerated the Japanese city of Hiroshima, for example, was a cannon that fired a shell of HEU into rings of HEU. In most cases, building such a bomb would require some ability to cast and machine uranium, a reasonable knowledge of the nuclear physics involved, and a good understanding of cannons and ballistics.[19] In many cases, an ability to do some chemical processing might also be needed (for example, to dissolve research reactor fuel containing HEU in acid, separate the HEU, and reduce the HEU to metal); but the chemical processing required is less sophisticated than some of the processing criminals routinely do in the illegal drug industry.[20]

It is impossible, however, to get a substantial nuclear yield from a gun-type bomb made from plutonium, because the neutrons always being emitted by the plutonium will set off the nuclear chain reaction prematurely, causing the bomb to blow itself apart. Hence, if the terrorists only had plutonium available (or did not have enough HEU for a gun-type bomb, which requires a large amount of material), terrorists who wanted a substantial nuclear yield would have to attempt the more difficult job of making an "implosion-type" device, in which explosives arranged around nuclear material compress it to a much higher density, setting off the nuclear chain reaction. While the terrorists' likelihood of success in making such a bomb would be lower, the danger

ber 2005.

[17] For a discussion of the vast difference between a safe, reliable, efficient weapon that can be carried on a missile, and a crude, inefficient, unsafe terrorist bomb that might be delivered in a rented truck, with references to relevant unclassified government studies, see Matthew Bunn and Anthony Wier, "Terrorist Nuclear Weapon Construction: How Difficult?" *Annals of the American Academy of Political and Social Science* 607 (September 2006). See also Anna M. Pluta and Peter D. Zimmerman, "Nuclear Terrorism: A Disheartening Dissent," *Survival* 48, no. 2 (Summer 2006).

[18] U.S. Congress, Office of Technology Assessment, *Nuclear Proliferation and Safeguards* (Washington, D.C.: OTA, 1977; available at http://www.wws.princeton.edu/ota/disk3/1977/7705/7705.PDF as of 09 July 2007), p. 140.

[19] For discussion, see Bunn and Wier, "Terrorist Nuclear Weapon Construction."; J. Carson Mark et al., "Can Terrorists Build Nuclear Weapons?" in *Preventing Nuclear Terrorism*, ed. Paul Leventhal and Yonah Alexander (Lexington, Mass: Lexington Books, 1987; available at http://www.nci.org/k-m/makeab.htm as of 07 August 2007).

[20] Professor James C. Warf, one of the leaders of the chemical processing programs in the Manhattan Project, has argued that the steps needed to get HEU from research reactor fuel in which it is mixed with other materials "are not difficult procedures, particularly for someone intent on acquiring an atomic explosive; one might say, in fact, that they are not beyond the ability of most students in introductory chemistry classes at the college level." See Committee on Science, Space, and Technology, *Conversion of Research and Test Reactors to Low-Enriched Uranium (LEU) Fuel*, U.S. Congress, House of Representatives, 98th Congress, 2nd Session, 25 September 1984, pp. 514-516.

cannot by any means be ruled out. Hence, plutonium separated from spent nuclear fuel, like HEU, must be protected from theft and transfer to terrorists.[21]

Even before the Afghan war, U.S. intelligence concluded that "fabrication of at least a 'crude' nuclear device was within al-Qa'ida's capabilities, if it could obtain fissile material."[22] Documents later seized in Afghanistan provided "detailed and revealing" information about the progress of al Qaeda's nuclear efforts that had not been available before the war.[23] As al-Muhajir's statement calling for nuclear experts to join the jihad suggests, al Qaeda has consistently attempted to recruit people with nuclear weapons expertise. Former CIA chief Tenet, in his memoir, recounts his conversation with Pervez Musharraf, in which the Pakistani president assured Tenet that Pakistani nuclear experts had dismissed the possibility that "men hiding in caves" could build a nuclear bomb. "Mr. President, your experts are wrong," Tenet says he replied, recounting the relative ease of making a crude "gun-type" nuclear bomb, and al Qaeda's efforts to get help from Pakistani nuclear scientists associated with Ummah Tameer-i-Nau (UTN), a group led by Mahmood, the lead scientist who sat down with bin Laden and Zawahiri to discuss nuclear weapons.[24]

The overthrow of the Taliban and the disruption of al Qaeda's old central command structure reduced the probability that al Qaeda would be able to pull off an operation as large and complex as acquiring nuclear bomb material and putting together a nuclear weapon. Unfortunately, however, the latest intelligence assessments suggest that al Qaeda's central command is reconstituting its ability to direct complex operations, from the border areas of Pakistan.[25] As then-Director of National Intelligence John Negroponte put it in his annual threat assessment in January 2007, al Qaeda's "core leadership… continue to plot attacks against our Homeland and other targets with the objective of inflicting mass casualties. And they continue to maintain active connections and relationships that radiate outward from their leaders' secure hideout in Pakistan to affiliates throughout the Middle East, northern Africa, and Europe." Negroponte specifically warned that while use of conventional explosives continues to be "the most probable" kind

[21] Bunn and Wier, "Terrorist Nuclear Weapon Construction." It is also important to note that any state or group that could make a nuclear bomb from weapon-grade plutonium would also be able to make a crude bomb from reactor-grade plutonium. A Nagasaki-type design made from reactor-grade plutonium would have an assured, reliable yield in the kiloton range, and a probable yield that is significantly higher. For an official U.S. government statement making these points, see U.S. Department of Energy, Office of Arms Control and Nonproliferation, *Nonproliferation and Arms Control Assessment of Weapons-Usable Fissile Material Storage and Excess Plutonium Disposition Alternatives*, DOE/NN-0007 (Washington, D.C.: DOE, 1997; available at http://www.osti.gov/bridge/servlets/purl/425259-CXr7Qn/webviewable/425259.pdf as of 2 January 2007), pp. 37-39. That statement concludes that "theft of separated plutonium, whether weapons-grade or reactor-grade, would pose a grave security risk."

[22] Commission on the Intelligence Capabilities of the United States Regarding Weapons of Mass Destruction, *Report to the President* (Washington, D.C.: WMD Commission, 2005; available at http://www.wmd.gov/report/ as of 09 July 2007), p. 276.

[23] Commission on the Intelligence Capabilities of the United States Regarding Weapons of Mass Destruction, *Report to the President*, p. 271.

[24] Tenet, *At the Center of the Storm*. [For a separate and similar account of this meeting see Ron Suskind, *The One Percent Doctrine: Deep Inside America's Pursuit of Its Enemies Since 9/11* (New York: Simon and Schuster, 2006), pp. 66-69.

[25] U.S. National Intelligence Council, *National Intelligence Estimate: The Terrorist Threat to the U.S. Homeland* (Washington, D.C.: Office of the Director of National Intelligence, 2007; available at http://www.dni.gov/press_releases/20070717_release.pdf as of 3 August 2007).

of al Qaeda attack, U.S. intelligence continues to "receive reports indicating that al Qaeda and other terrorist groups are attempting to acquire chemical, biological, radiological and nuclear weapons or material."[26] Unfortunately, the physics of the problem suggests that a terrorist cell of relatively modest size, with no large fixed facilities that would draw attention, might well be able to make a crude nuclear bomb—and the world might never know until it was too late.[27]

Huge Stockpiles of Nuclear Weapons and Material Exist Worldwide

An important element of the threat of nuclear theft and terrorism is the massive size and broad distribution of the global stockpiles of nuclear weapons and the materials needed to make them.

Today, more than a decade after the end of the Cold War, there are still more than 25,000 assembled nuclear weapons in the world.[28] While Russia and the United States own some 95% of these weapons, nine countries possess such weapons, including Russia, the United States, France, China, the United Kingdom (which are the five nuclear weapon states under the Nonproliferation Treaty [NPT]), along with the states outside the NPT, Israel, India, Pakistan, and, most recently, North Korea. In addition to these nine countries that possess nuclear weapons of their own, U.S. nuclear weapons are reportedly located in six other countries—one other nuclear weapon state (the United Kingdom) and five non-nuclear-weapon states (Germany, the Netherlands, Belgium, Italy, and Turkey).[29]

World stockpiles of separated plutonium and HEU, the essential ingredients of nuclear weapons, amount to well over 2,300 tons—enough to manufacture over 200,000 nuclear weapons.[30] Less than

[26] John D. Negroponte, "Annual Threat Assessment of the Director of National Intelligence" (Washington, D.C.: 2007; available at http://www.dni.gov/testimonies/20070118_transcript.pdf as of 10 July 2007).

[27] For discussions of official assessments of the complexity of the operation and the number of people required, see Bunn and Wier, "Terrorist Nuclear Weapon Construction." For a particular scenario involving a cell of 19 people working for roughly a year (probably more than is actually required for some types of crude bomb), see Peter D. Zimmerman and Jeffrey G. Lewis, "The Bomb in the Backyard," *Foreign Policy*, no. 157 (November/December 2006), pp. 32-39.

[28] This includes an estimated 16,000 remaining in Russia's stockpiles; over 10,000 remaining in the U.S. nuclear stockpiles; and over 1,000 warheads in the combined total of other countries' stockpiles. See Robert S. Norris and Hans S. Kristensen, "NRDC Nuclear Notebook: Global Nuclear Stockpiles, 1945-2006," *Bulletin of the Atomic Scientists* 62, no. 4 (July/August 2006), pp. 64-66.

[29] As a result of the 1991 Presidential Nuclear Initiatives, U.S. nuclear weapons have been removed from South Korea and from surface ships, which previously regularly carried them to countries around the world. The deployments in Europe, and on submarines, are believed to be the only remaining U.S. nuclear weapons deployments beyond U.S. shores. For a detailed discussion of the remaining U.S. nuclear weapons in Europe, see Hans M. Kristensen, *U.S. Nuclear Weapons in Europe: A Review of Post-Cold War Policy, Force Levels, and War Planning* (Washington, D.C.: Natural Resources Defense Council, 2005; available at http://www.nrdc.org/nuclear/euro/euro.pdf as of 25 July 2007). See also Kristensen, "Where the Bombs Are, 2006," *Bulletin of the Atomic Scientists* 62, no. 6 (November/December 2006; available at http://thebulletin.metapress.com/content/h2125x87046603r5/fulltext.pdf as of 12 June 2007).

[30] These figures include only plutonium separated from spent fuel, not the larger amount of plutonium in spent fuel. They include the plutonium and HEU in intact weapons and their components, as well as additional material stored in a wide range of other forms (the largest categories being metals and oxides); the plutonium figure includes both separated plutonium in military stockpiles and separated "reactor-grade" plutonium in civilian stockpiles, both of which are usable in nuclear explosives. (The weapons-usability of reactor-grade plutonium is discussed in detail in Chapter 4.) They include also plutonium and HEU in fabricated

a hundredth of one percent of the vast stockpile of weapons-usable nuclear materials in countries such as Russia or the United States would be enough for several terrorist nuclear bombs, highlighting the need for airtight security throughout these countries' nuclear complexes. Neither of these materials occurs in significant quantities in nature; these stockpiles of weapons and materials have all been intentionally produced by human beings in the first six decades of the nuclear age.

Unlike nuclear weapons, separated plutonium and HEU have both military and civilian uses. HEU is used as fuel in civilian research reactors and icebreaker reactors, and as targets for producing medical isotopes. Plutonium is separated from commercial spent fuel by reprocessing and, mixed with uranium in a mixed-oxide (MOX) fuel, is recycled as fuel for power reactors.

Roughly 140 research reactors in some 40 countries continue to operate with HEU as their fuel.[31] Some of these do not have enough nuclear material on-site for a bomb, but many do—as do many associated facilities, such as fuel fabrication plants. All told, there are an estimated 128 research reactors or associated facilities worldwide that possess at least 20 kilograms of HEU, enough to make a bomb.[32] Of these, 41 are fuel facilities rather than research reactors themselves.[33]

fuel elements. The definition used to determine what should be included is almost the same as the International Atomic Energy Agency's definition of "unirradiated direct use material"—that is, all materials containing plutonium and HEU which do not emit more than 100 rem/hr at 1 meter and are not "practically irrecoverable." International Atomic Energy Agency, *IAEA Safeguards Glossary* (Vienna: IAEA, 2001; available at http://www-pub.iaea.org/MTCD/publications/PDF/nvs-3-cd/Start.pdf as of 09 July 2007). The difference from that definition is that no attempt has been made in these figures to exclude civil HEU emitting more than 100 rem/hr at 1 meter; however, the overwhelming majority of civil irradiated HEU is not emitting sufficient radiation to greatly reduce the proliferation concerns it poses. These figures are from David Albright and Kimberly Kramer, eds., *Global Fissile Material Inventories* (Washington, D.C.: Institute for Science and International Security, 2004; available at http://www.isis-online.org/global_stocks/old/tableofcontents.html as of 25 July 2007). These figures are updates of the detailed review of these stockpiles provided in David Albright, Frans Berkhout, and William B. Walker, *Plutonium and Highly Enriched Uranium, 1996: World Inventories, Capabilities, and Policies* (Solna, Sweden; Oxford, UK; and New York: Stockholm International Peace Research Institute (SIPRI) and Oxford University Press, 1996). The HEU figures are for tons of 90% enriched equivalent, so if, for example, a country had two tons of 45% enriched material, that would count as one ton in these estimates.

[31] The Department of Energy's most recent list includes 207 HEU-fueled reactors, of which 48 were already converted or shut down as of the end of 2006, and 15 were icebreaker reactors (important to address, but in a somewhat different category from research reactors), for a total of 144 research reactors still operating with HEU at the time the list was prepared. (Data provided by DOE, March 2007.) Similarly, data compiled by Ole Reistad (Institute of Physics, University of Science and Technology at Trondheim, and Norwegian Radiation Protection Authority), includes 146 reactors operating with HEU fuel as of late 2007, of which five are plutonium or tritium production reactors, one is a commercial reactor, and one uses plutonium fuel, leaving 139 that are research reactors. (Personal communication, June 2007.) Reistad and colleagues have somewhat modified data forthcoming, reflecting ongoing reactor conversions and shutdowns. See Ole Reistad, Morten Bremer Maerli, and Styrkaar Hustveit, *Non-Explosive Nuclear Applications Using Highly Enriched Uranium—Conversion and Minimization Towards 2020* (Princeton, N.J.: International Panel on Fissile Materials, forthcoming 2007).

[32] U.S. Congress, Government Accountability Office, *Nuclear Nonproliferation: DOE Needs to Take Action to Further Reduce the Use of Weapons-Usable Uranium in Civilian Research Reactors*, GAO-04-807 (Washington, D.C.: GAO, 2004; available at http://www.gao.gov/new.items/d04807.pdf as of 10 July 2007), p. 28. Twenty kilograms of HEU would not be enough for a gun-type bomb, but would be sufficient, depending on the enrichment level, for an implosion-type bomb.

[33] Interviews with Argonne National Laboratory and DOE officials, February 2005.

There are an estimated 65 tons of HEU in civilian use worldwide.[34]

To date, the number of countries reprocessing and recycling plutonium is smaller, though the quantities involved are far higher, with roughly 20 tons of plutonium being reprocessed per year in recent years, and roughly 10 tons being used as fuel. Because of that mismatch, as of the end of 2005, over 250 tons of separated, weapons-usable plutonium existed in civilian stockpiles worldwide—a figure equal to all the plutonium in all the world's nuclear weapon stockpiles.[35] As a result, while roughly half of the estimated world stockpile of roughly 500 tons of separated plutonium at the end of 2005 was civilian, only about 3% of the estimated world stockpile of HEU was civilian. See Figure 1.1 and Figure 1.2.

Because of their civilian uses, separated plutonium and HEU are much more broadly distributed than nuclear weapons, existing in hundreds of buildings in well over 40 countries. Nine countries have two metric tons or more of these weapons-usable nuclear materials, including all of the five NPT nuclear weapon states, India, Germany, Japan, and Belgium.[36] Thus there are three non-nuclear-weapon states under the NPT with enough weapons-usable nuclear material on their soil for hundreds of nuclear weapons.

In addition to the countries with tons of plutonium or HEU, there are roughly 26 other countries with "Category I" quantities of these materials—that is, enough material that under international standards, the highest levels of security are required.[37] Thus, nuclear weapons or enough nuclear material to pose a seri-

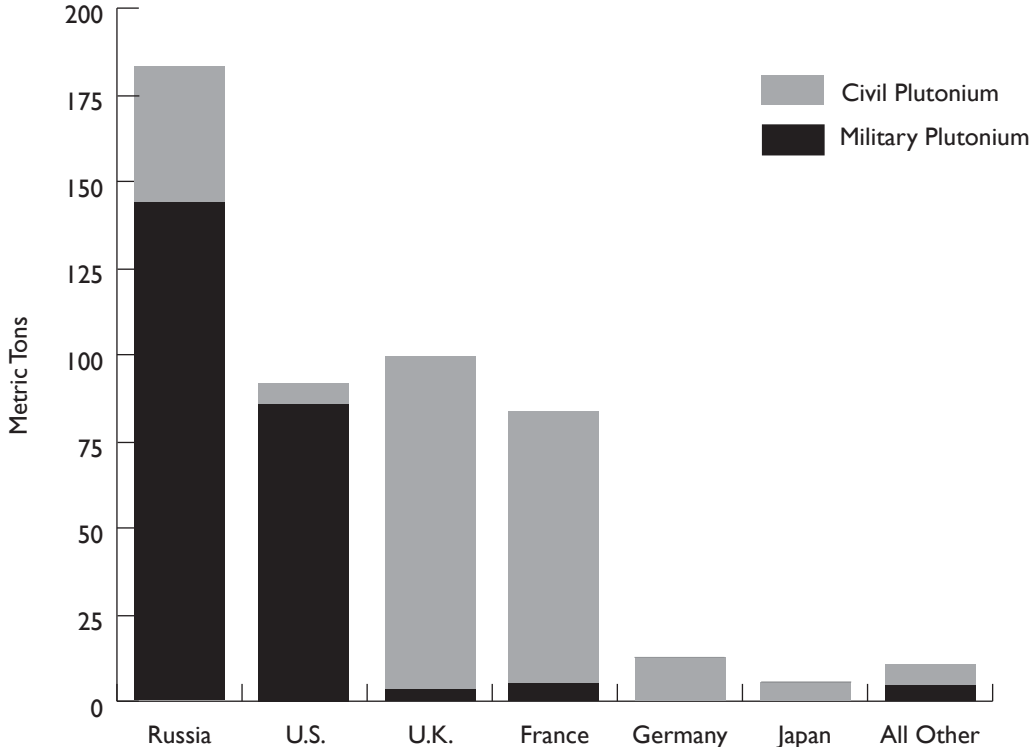
[34] See David Albright and Kimberly Kramer, "Civil HEU Watch: Tracking Inventories of Civil Highly Enriched Uranium," in *Global Stocks of Nuclear Explosive Materials* (Washington, D.C.: Institute for Science and International Security, 2005; available at http://www.isis-online.org/global_stocks/end2003/civil_heu_watch2005.pdf as of 25 July 2007). Albright and Kramer estimate that there are 175 tons of HEU they designate as civilian, including 50 tons in "power and research reactor programs" and 125 tons of U.S. excess HEU (these are rounded figures). But they point out that 15 tons of the U.S. excess is research reactor fuel, and I have therefore included this amount in the total of civilian HEU. I have not included the remainder of the U.S. excess, as Albright and Kramer do, in order to avoid giving an exaggerated impression of the scale of civilian HEU use around the world.

[35] See Harold Feiveson et al., "Appendix 12c: Fissile Materials: Global Stocks, Production, and Elimination," in *SIPRI Yearbook 2007: Armaments, Disarmament, and International Security* (Oxford: Oxford University Press for the Stockholm International Peace Research Institute, 2007).

[36] Drawn from David Albright and Kimberly Kramer, *Global Stocks of Nuclear Explosive Materials* (Washington, D.C.: Institute for Science and International Security, 2005; available at http://www.isis-online.org/global_stocks/end2003/tableofcontents.html as of 07 August 2007). Kazakhstan was once in this category, but is no longer. Nearly three tons of medium-enriched material (in the 20-30% range) existed at Aqtau, the site of the BN-350 fast-neutron reactor, but the fresh fuel for that facility has since been moved to the fuel processing facility at Ust-Kamenogorsk and blended down to LEU. "Government of Kazakhstan and NTI Mark Success of HEU Blend-Down Project: Material Could Have Been Used to Make up to Two Dozen Nuclear Bombs" (Ust-Kamenogorsk, Kazakhstan: Nuclear Threat Initiative, 8 October 2005; available at http://www.nti.org/c_press/release_Kaz_100805.pdf as of 25 July 2007). Kazkahstan still has HEU for its research reactors, but those stocks are well below the two-ton threshold mentioned in the text. Some past accountings of Kazakhstan's HEU stock may have included irradiated BN-350 fuel, which is likely to be less than 20% enriched after burnup. Similarly, with the closure of the Belgonucléaire plutonium fuel fabrication facility, Belgium has either left the category of countries with stocks of two tons or more, or soon will.

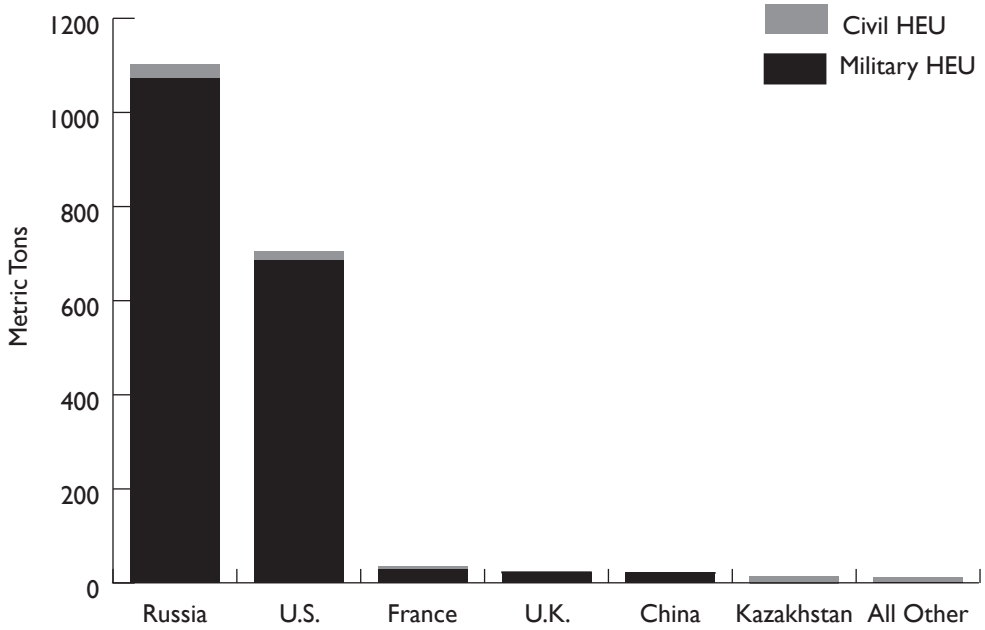
[37] Under international standards, five kilograms of U-235 contained in HEU or 2 kilograms of plutonium constitutes a "Category I" quantity. These 26 countries include the three other non-NPT states and 23 additional NPT non-nuclear-weapon states. Of these 26, seven are developing countries and nine are transition countries (that is, former communist countries). Drawn from Albright and Kramer, *Global Stocks of Nuclear Explosive Materials*.

Figure 1.1:
Global Military and Civil Stockpiles of Separated Plutonium



Source: Adapted from David Albright and Kimberly Kramer, *Global Stocks of Nuclear Explosive Materials* (Washington, D.C.: Institute for Science and International Security, July 2005, available as of 2 January 2007 at http://www.isis-online.org/global_stocks/end2003/tableofcontents.html).

Figure 1.2:
Global Stockpiles of Military and Civil HEU



Source: Adapted from Albright and Kramer, *Global Stocks of Nuclear Explosive Materials.*

ous concern exist in a total of some 36 countries. Security for these materials in all of these countries must be effective enough to ensure that plausible terrorist and criminal threats, both from insiders and outsiders, can be reliably defeated. Finally, there are another 13 countries with one to a few kilograms of HEU or separated plutonium, all of them non-nuclear-weapon states.[38]

Many projections suggest that nuclear energy may grow substantially over the next several decades, and spread to additional countries. Such growth will require additional efforts to ensure that nuclear facilities are effectively protected from sabotage. It is essential to ensure that this growth will not also lead to an additional spread of separated plutonium and HEU around the world.

Transport. In addition to fixed facilities, nuclear warheads and weapons-usable materials must also be effectively secured while they are being transported. Indeed, transport is the stage of these items' life cycle that is most vulnerable to overt, forcible theft. When these items are being shipped from place to place, it is impossible to provide the multiple layers of detection and delay that can be put in place at a fixed site. This problem is typically addressed with measures such as armed guards accompanying the transports, vehicles with special protection against hijack and sabotage, secrecy concerning the schedule and route of the transports, and continuous or frequent tracking of the transport en route.

The scale and frequency of transport, particularly from site to site within countries, is huge. Hundreds of nuclear warheads are transported from deployment sites to warhead storage and assembly/disassembly facilities, or from such facilities back to deployment sites, each year, in both Russia and the United States—and presumably, to a lesser extent, in other countries with nuclear weapons. In Russia, for example, the U.S. Cooperative Threat Reduction (CTR) program has been planning to pay for roughly 70 shipments per year of nuclear warheads to dismantlement and storage sites, carrying 20-30 warheads each[39]—in addition to however many shipments for operational purposes (which are not paid for by the United States) take place. In the United States, within DOE alone, the Secure Transportation Asset program carries out nearly 100 secure transports of either nuclear warheads or weapons-usable nuclear material a year, at an annual cost that is now in the range of $140 million per year.[40] That does not include Department of Defense transport of nuclear weapons and materials, or private transport of nuclear materials.

Huge numbers of transports of HEU and separated plutonium also take place every year, which must also be protected. By one estimate, for example, roughly 100 commercial plutonium shipments occur per year, most of which contain over 100 kilograms of weapons-usable plutonium

[38] Drawn from Albright and Kramer, *Global Stocks of Nuclear Explosive Materials*.

[39] U.S. Department of Defense, *Cooperative Threat Reduction Annual Report to Congress: Fiscal Year 2006* (Washington, D.C.: U.S. Department of Defense, 2005).

[40] In Fiscal Year 2006 for example, the program carried out 93 secure trips carrying nuclear weapons or weapons-usable nuclear material from one place to another—an average of almost two a week. See U.S. Department of Energy, *FY 2006 Congressional Budget Request: National Nuclear Security Administration* (Washington, D.C.: DOE, 2005; available at http://www.cfo.doe.gov/budget/06budget/Content/Volumes/Vol_1_NNSA.pdf as of 10 July 2007), pp. 305-309. *FY 2008: Congressional Budget Request: National Nuclear Security Administration* (Washington, D.C.: DOE, 2007; available at http://www.mbe.doe.gov/budget/08budget/Content/Volumes/Vol_1_NNSA.pdf as of 12 June 2007), pp. 307-314.

in a single shipment.[41] In France in particular, which has the world's most active plutonium recycling program, many tons of plutonium separated at the La Hague reprocessing plant each year travel by scores of truck shipments, as plutonium oxide, to the fuel fabrication facility at Marcoule; once fabricated into fuel elements, this plutonium is then shipped to numerous reactors both in France and in other countries.[42] HEU shipments for research reactor fuel take place frequently around the world (though many of these are intentionally kept to a small amount of HEU at a time, for security reasons). The adequacy of security for nuclear material transports around the world has been a subject of controversy for many years; the fact is that it is extraordinarily difficult to provide the same level of security for items in transport as they can have at large fixed sites. [43]

Some Nuclear Stockpiles Are Dangerously Insecure

Those seeking material for a nuclear bomb will go wherever it is easiest to steal, or buy it from anyone willing to sell. Thus, security for bomb material is only as good as its weakest link. Inadequately secured nuclear bomb material anywhere is a threat to everyone, everywhere. Yet today, security for the world's vast and widely distributed nuclear stockpiles varies enormously, from excellent to appalling.

Some facilities with nuclear weapons, plutonium, or HEU are equipped with substantial numbers of well-equipped and well-trained guards, impressive double fences, intrusion detectors, multiple layers of barriers, and a wide range of measures to address insider threats as well. Others have virtually none of these security measures in place. At some civilian research reactors fueled with HEU—many of which are on university campuses—the security in place literally amounts to a single night watchman and a chain-link fence (or less).

Most of the nuclear facilities in the world, including many in the United States, would not be able to provide a reliable defense against attacks as large as terrorists have already proved they can mount, such as the four coordinated, independent teams of four to five suicidal terrorists each that struck on September 11, 2001, or the 30-plus terrorists armed with automatic weapons and explosives who seized a thousand hostages at the school in Beslan, Russia in September 2004. A conspiracy of several insiders working together—possibly coerced by terrorists to do so, as in past cases where insiders' families have been kidnapped—would be even more difficult to defend against.

In Russia and the other states of the former Soviet Union, security for nuclear stockpiles has improved substantially over the last fifteen years. The most egregious security problems of the 1990s—gaping holes in fences, lack of any detector to set off an alarm if pluto-

[41] David Albright, *Shipments of Weapons-Usable Plutonium in the Commercial Nuclear Industry* (Washington, D.C.: Institute for Science and International Security, 2007; available at http://www.isis-online.org/global_stocks/end2003/plutonium_shipments.pdf as of 3 January 2007).

[42] Albright estimates that shipments of plutonium oxide powder from La Hague to Marcoule account for nearly half of total global plutonium shipments. Albright, *Shipments of Weapons-Usable Plutonium*. See also the discussion in Ronald E. Timm, *Security Assessment Report for Plutonium Transport in France* (Paris: Greenpeace International, 2005; available at http://greenpeace.datapps.com/stop-plutonium/en/TimmReportV5.pdf as of 09 July 2007).

[43] For a particularly detailed analysis of transport security in France, arguing that current procedures are worse than what would be characterized as "high risk" and therefore prohibited within the DOE system, justifying a new category of "extreme risk," see Timm, *Security Assessment Report for Plutonium Transport in France*.

nium or HEU was being carried out the door—have generally been fixed, even at sites where U.S.-funded upgrades have not been completed or have not taken place. It is unlikely there is any site in Russia where the threats that succeeded in the 1990s—such as one individual walking through a hole in a fence, snapping a padlock on a shed with a steel bar, stuffing his backpack with HEU, and retracing his steps with no one noticing until hours later—would succeed today. Most importantly, Russia's economy has stabilized and has been growing steadily for years; nuclear workers are getting paid an above-average wage, on time, largely ending the desperation that motivated some nuclear thefts or theft attempts of the 1990s; and the central government has established much firmer control over key sectors and facilities.

But as discussed later in this chapter, stockpiles in the former Soviet Union still pose some of the world's most urgent risks of nuclear theft. Russia has the world's largest stockpiles of nuclear weapons and materials, dispersed in the world's largest number of buildings and bunkers; nuclear security measures that, despite improvements, still have significant weaknesses; and potentially fearsome adversary capabilities that terrorists and thieves have demonstrated they can bring to bear, from large groups of well-armed, well-trained terrorists to insider theft conspiracies. Russia remains the only country where senior officials have confirmed that terrorist teams have been carrying out reconnaissance at nuclear weapon storage sites.[44]

Pakistan has a relatively small nuclear stockpile, believed to be heavily guarded, but huge threats, including armed elements of al Qaeda and other jihadi terrorist groups, and from insiders with a demonstrated willingness to sell sensitive nuclear technology throughout the world, and in some cases, demonstrated sympathy for extreme jihadi causes. If al Qaeda terrorists can twice come close to assassinating President Musharraf with help from Pakistani military officers, who can rule out the possibility that other military officers guarding nuclear weapons might be convinced to help al Qaeda?

HEU-fueled research reactors around the world—particularly those with substantial quantities of fresh or lightly irradiated HEU—also pose urgent risks of nuclear theft. While the materials available at most such facilities would require some chemical processing before they could be used in a bomb, most groups with the skills needed to make a nuclear bomb from HEU metal would be able to put together the skills needed to get HEU metal from HEU research reactor fuel.[45] Many of these facilities have extraordinarily modest security in place, sometimes amounting to a night watchman and a chain-link fence (or less, in some cases).

[44] Lt. Gen. Igor Valynkin, commander of the force that guards Russia's nuclear weapons, reported two incidents of terrorist teams carrying out such reconnaissance. See, for example, "Russia: Terror Groups Scoped Nuke Site."; Koryashkin, "Russian Nuclear Ammunition Depots Well Protected—Official." The Russian state newspaper reported those two incidents, and two more involving terrorist reconnaissance on warhead transport trains. Vladimir Bogdanov, "Propusk K Beogolovkam Nashli U Terrorista (a Pass to Warheads Found on a Terrorist)," *Rossiskaya Gazeta*, 1 November 2002.

[45] The chemistry required is in most cases less sophisticated than the chemistry already routinely used in the production of illegal drugs. One of the leaders of the chemistry effort in the Manhattan Project has said that "[t]hese are not difficult procedures, particularly for someone intent on acquiring an atomic explosive; one might say, in fact, that they are not beyond the ability of most students in introductory chemistry classes at the college level." See Committee on Science, Space, and Technology, *Conversion of Research and Test Reactors to Low-Enriched Uranium (LEU) Fuel*, U.S. Congress, House of Representatives, 98th Congress, 2nd Session, 25 September 1984, pp. 514-516.

Remarkably, years after the 9/11 attacks, with overwhelming evidence that terrorists are seeking to get stolen nuclear weapons material, the world has still been unable to agree on any specific and binding minimum standards for how well nuclear weapons or the materials to make them should be secured. Despite the danger that inadequately secured plutonium or HEU in any state poses to all other states, security for these stockpiles is left almost entirely to the discretion of each country where these weapons and materials exist. Even more remarkable, no effort to put specific and binding global standards in place is now underway.

It is important to understand that the nuclear Nonproliferation Treaty (NPT) does not contain any provisions requiring states to secure nuclear material from theft.[46] Similarly, the IAEA safeguards system is designed only to verify that states have not diverted nuclear material for nuclear explosives, not to protect material from theft or even to confirm that the state that owns the material is providing adequate protection; so the statement that nuclear material is under safeguards is almost unrelated to the question of whether that material is adequately secured or not.[47] There is now a legally binding U.N. Security Council resolution requiring all states to provide "appropriate effective" security for any nuclear stockpiles they may have—but no one has yet defined what the essential elements of an effective system required by this resolution might be.[48] A negotiated amendment to the Convention on the Physical Protection of Nuclear Material will create at least some very general requirements for security for nuclear stockpiles, but the convention does not apply to military stockpiles; the rules it sets are extraordinarily general (specifying, for example, that countries should set and enforce rules for how secure their nuclear facilities should be, but not what those rules should say); the amendment will not enter into force for years to come; and many countries have not yet signed up to the amendment.[49] The 2005 International Convention for the Suppression of Acts of Nuclear Terrorism entered into force in July 2007. It requires parties to "make every effort" to put in place "appropriate" security for their nuclear stockpiles, but it does not further define what that means and many countries are not yet parties to the agreement.[50]

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[46] One of the treaty's negotiators has emphasized that if he knew then what he knows now, he would have sought to include such provisions. See remarks by George Bunn at International Atomic Energy Agency, *Proceedings of the Symposium on International Safeguards: Verification and Nuclear Material Security, Vienna, 29 October-2 November 2001* (Vienna: IAEA, 2001).

[47] IAEA safeguards are not *quite* unrelated to physical protection, for two reasons. First, inspectors do sometimes notice troubling security weaknesses and report them to others who may be able to convince the inspected state to ask for assistance in improving security. Second, the requirement that non-nuclear-weapon states have to prepare comprehensive reports to the IAEA on their nuclear inventories and changes in them, and to subject those reports to critical IAEA review and inspection, imposes an international discipline that tends to improve the quality of nuclear material accounting, which is one element in an overall nuclear security system.

[48] For the text of UN Security Council resolution (UNSCR) 1540, see United Nations, "1540 Committee" (New York: UN, 2005; available at http://disarmament2.un.org/Committee1540/meeting.html as of 09 July 2007). The potential to use this resolution as a foundation from which to build effective global nuclear security standards is discussed in Chapter 3.

[49] For the text of the amended convention, see *Amendment to the Convention on the Physical Protection of Nuclear Material* (Vienna: International Atomic Energy Agency, 2005; available at http://www-pub.iaea.org/MTCD/Meetings/ccpnmdocs/cppnm_proposal.pdf as of 09 July 2007).

[50] For the full text, see *International Convention for the Suppression of Acts of Nuclear Terrorism* (New York: United Nations, 2005; available at http://www.

IAEA recommendations provide the most specific international standards for nuclear security that now exist, but even these are quite vague: they specify, for example, that significant amounts of weapons-usable nuclear material should be stored in a place with a fence and intrusion detectors, but they say nothing about how strong the fence should be or how good the intrusion detectors should be. They recommend 24-hour guards, but do not require that they be armed, and say nothing about how numerous or well-equipped or well-trained they should be. They recommend that states establish a "design basis threat" that their facilities with significant amounts of weapons-usable material be required to defend against—but they do not say anything about what that threat should be.[51] Most states try to ensure that their facilities meet the IAEA recommendations, and many have agreements with nuclear suppliers that require them to do so.

Because of the vagueness of the IAEA recommendations—which were last revised in 1999, long before the 9/11 attacks—many countries have nuclear security systems that comply with "international standards" but nevertheless leave their nuclear stockpiles dangerously vulnerable to the kinds of threats that thieves and terrorists have shown they can pose.

un.int/usa/a-59-766.pdf as of 25 July 2007). A listing of the states that have signed and ratified was available at http://untreaty.un.org/ENGLISH/bible/englishinternetbible/partI/chapterXVIII/treaty19.asp as of 10 September 2007.

[51] For the text of the IAEA recommendations, see International Atomic Energy Agency, *The Physical Protection of Nuclear Material and Nuclear Facilities*, INFCIRC/225/Rev.4 (Corrected) (Vienna: IAEA, 1999; available at http://www.iaea.or.at/Publications/Documents/Infcircs/1999/infcirc225r4c/rev4_content.html as of 22 December 2006). The development of these recommendations is described in Chapter 5.

Nuclear Theft Is an Ongoing Reality

Because of these security weaknesses, theft of the essential ingredients of nuclear weapons is not a hypothetical worry, it is an ongoing reality. The IAEA database on nuclear smuggling includes 15 incidents of real theft and smuggling of separated plutonium or HEU confirmed by the states involved.[52] There are additional incidents that certainly occurred—named human beings were arrested, tried, convicted, and have confessed in detail—but that the relevant states have not yet confirmed to the IAEA.[53]

Most recently, in February 2006, Russian citizen Oleg Khinsagov was arrested in

[52] At this writing, the most recent public accounting of these incidents was in International Atomic Energy Agency, *Incidents Involving HEU and Pu Confirmed to the ITDB, 1993-2006* (Vienna: IAEA, 2007; available at http://www.iaea.org/NewsCenter/Focus/NuclearSecurity/pdf/heu-pu_1993-2006.pdf as of 10 September 2007). That list included 18 incidents with plutonium or HEU, but three of these appeared to involve inadvertent losses (one 2006 incident in Germany, and 2005 incidents in Japan and the United States). Two incidents have been removed from previous IAEA tallies, as one plutonium incident involved such a small amount of material it was reclassified as a radioactive source incident, and one incident previously tracked as an HEU case was confirmed to be LEU. (Personal communication from Richard Hoskins, IAEA Office of Nuclear Security, October 2006.)

[53] For a useful accounting, now a few years old, see "Confirmed Proliferation-Significant Incidents of Fissile Material Trafficking in the Newly Independent States (NIS), 1991-2001" (Monterey, Cal.: Center for Nonproliferation Studies, Monterey Institute of International Studies, 30 November 2001; available at http://cns.miis.edu/pubs/reports/traff.htm as of 09 July 2007). For an interview with Leonid Smirnov, who stole 1.5 kilograms of 90% enriched HEU in 1992, see "Frontline: Loose Nukes: Interviews" (Public Broadcasting System, 1996; available at http://www.pbs.org/wgbh/pages/frontline/shows/nukes/interviews/ as of 25 July 2007). For a detailed account of a similarly alarming 1993 case, see Oleg Bukharin and William Potter, "Potatoes Were Guarded Better," *Bulletin of the Atomic Scientists* 51, no. 3 (May-June 1995), pp. 46-50.

Georgia (along with three Georgian accomplices) with some 100 grams of HEU enriched to 89% U-235.[54] The arrest was part of a sting operation in which a Georgian government agent posed as an Islamist buyer for a "serious organization." Khinsagov claimed to have access to 2-3 kilograms of HEU, but the veracity of that claim has not been confirmed. Khinsagov was convicted and sentenced to eight years in prison. The material was reportedly smuggled through the separatist region of South Ossetia, on the Georgian-Russian border, which has become a haven for smugglers of all kinds. The U.S. ambassador to Georgia, John F. Tefft, warned that this seizure "highlights how smuggling and loose border control, associated with Georgia's separatist conflicts," pose a threat "not just to Georgia but to all the international community."[55]

The most important question—which as yet has no answer—is how many nuclear thefts may have occurred that have not been detected. Do the known cases represent nearly all the nuclear thefts that have occurred, or, as in the case of drug smuggling, do authorities only detect and stop a small fraction of the overall traffic? The U.S. National Intelligence Council continues to assess that "it is likely that undetected smuggling has occurred, and we are concerned about the total amount of material that could have been diverted over the last 15 years."[56] Former CIA Director Porter Goss testified to Congress that sufficient material was unaccounted for that he could not provide assurances that enough material for a bomb had not already been stolen.[57]

State Transfers to Terrorists Are a Real, but Lower, Risk

Conceivably, terrorists might get nuclear material or a nuclear weapon consciously provided by a state, rather than stolen weapons or material. President Bush and many other officials of his administration believe, in his words, that "rogue states are clearly the most likely sources of chemical and biological and nuclear weapons for terrorists."[58] This belief determines the policy prescription: if the principal danger of terrorists acquiring

[54] For a useful summary of this case, see Elena Sokova, William C. Potter, and Cristina Chuen, "Recent Weapons Grade Uranium Smuggling Case: Nuclear Materials Are Still on the Loose" (Monterey, Calif.: Center for Nonproliferation Studies, Monterey Institute of International Studies, 26 January 2007; available at http://cns.miis.edu/pubs/week/070126.htm as of 09 July 2007).

[55] Lawrence Scott Sheets and William J Broad, "Smuggler's Plot Highlights Fear over Uranium," *New York Times*, 25 January 2007 (available at http://fairuse.100webcustomers.com/sf/nyt1_25_7_5.htm as of 09 July 2007).

[56] U.S. National Intelligence Council, *Annual Report to Congress on the Safety and Security of Russian Nuclear Facilities and Military Forces* (Washington, D.C.: Central Intelligence Agency, 2006; available at http://www.fas.org/irp/nic/russia0406.html as of 16 May 2007).

[57] See testimony in Select Committee on Intelligence, *Current and Projected National Security Threats to the United States*, U.S. Senate, 109th Congress, 16 February 2005 (available at http://www.fas.org/irp/congress/2005_hr/shrg109-61.pdf as of 4 January 2007). Goss was not saying that the CIA had definite information that enough material for a bomb was missing, only that the accounting uncertainties are large enough that he could not confirm that was not the case. The same is true in the United States; some two tons of U.S. plutonium, for example, enough for hundreds of nuclear bombs, is officially considered "material unaccounted for." See U.S. Department of Energy, *Plutonium: The First 50 Years: United States Plutonium Production, Acquisition, and Utilization from 1944 through 1994* (Washington, D.C.: DOE, 1996; available at http://www.fas.org/sgp/othergov/doe/pu50y.html as of 09 July 2007).

[58] President George W. Bush, "President Speaks on War Effort to Citadel Cadets: Remarks by the President at the Citadel" (Washington, D.C.: The White House, Office of the Press Secretary, 11 December 2001; available at http://www.whitehouse.gov/news/releases/2001/12/20011211-6.html as of 07 August 2007).

weapons of mass destruction is that hostile states might provide them, then the key element of the solution is to take on those hostile states and make sure that they do not provide them. This is the idea that animates the preemptive doctrine laid out in the administration's *National Security Strategy*, and that was fundamental to the argument for going to war with Iraq.

While this possibility cannot be ruled out, it is likely to be a small fraction of the overall risk of nuclear terrorism. Under all but a few circumstances, states are extremely unlikely to consciously decide to transfer a nuclear weapon or weapons-usable nuclear materials in their possession to a terrorist group. Such a decision would mean transferring the most awesome military power the state had ever acquired to a group over which it had little control—a particularly unlikely step for dictators or oligarchs obsessed with controlling their states and maintaining power. If the terrorists actually used the transferred capability against the United States or one of its allies, there would be a substantial chance that the source of the weapon or material would be traced back to the state that provided it, and that the resulting retaliation would be overwhelming, almost certainly obliterating the government that decided on such a transfer.

In some cases—such as in the limited dealings between Saddam Hussein's government and al Qaeda—the state would have to have some concern that the capability might be turned back on the state that provided it (at least in the form of blackmail, if not actual use); al Qaeda, after all, has as its core objective the overthrow of all the secular regimes of the Arab world, including, while it existed, Saddam Hussein's government. Hence, prior to the 2003 U.S.-led invasion of Iraq, the CIA concluded that Baghdad was "drawing a line short" of any form of terrorist attacks against the United States (conventional or unconventional); only if Saddam Hussein concluded that that a U.S. attack was inevitable anyway might he consider the "extreme step" of providing weapons of mass destruction to Islamist terrorists, as his "last chance to exact vengeance."[59]

Similarly, in the case of North Korea—the next state most commonly mentioned as one that might decide to transfer nuclear weapons or materials to terrorist groups—putting such apocalyptic power in the hands of a group outside of the North's control would be fundamentally contrary to Pyongyang's desire to control every aspect of national life, and would be an immense gamble with the very future existence of the North Korean regime. Given that regime survival appears to be the highest goal of the Pyongyang government, this appears extremely unlikely—unless the regime concludes that its overthrow is inevitable (as the CIA worried would occur in Iraq's case) or becomes so desperate that the revenue from a nuclear sale came to be seen as the only route to its survival. A decision by the Iranian government to provide nuclear weapons or materials to al Qaeda terrorists (in the future, when the Iranian government might have such items to provide) also appears extraordinarily unlikely, particularly as the Sunni al Qaeda has been sponsoring widespread attacks on Shiites in Iraq, Pakistan, and elsewhere.

Nuclear Smuggling Is Extraordinarily Hard to Stop

Whether terrorists got a nuclear bomb or nuclear material from a state or after

[59] George J. Tenet, "Letter to Senator Bob Graham" (Washington, D.C.: U.S. Central Intelligence Agency, 7 October 2002; available at http://www.globalsecurity.org/wmd/library/news/iraq/2002/iraq-021007-cia01.htm as of 10 July 2007).

it had been stolen, it would be extraordinarily difficult to find and recover it, or to stop it from being smuggled within or between countries. Attempting to protect the United States from nuclear terrorism by detecting and stopping nuclear contraband at the U.S. borders is like a football team defending at its own goal line—but with that goal line stretched to thousands of kilometers, much of it unguarded wilderness, with millions of people and vehicles legitimately crossing it every year.[60] After all, thousands of tons of illegal drugs and hundreds of thousands of illegal immigrants cross U.S. borders every year, despite massive efforts to stop them.[61]

The materials needed to make a nuclear bomb are small and easy to hide. Terrorists would need about 50 kilograms (110 pounds) of HEU for the simplest gun-type bomb—an amount of material roughly the size of a six-pack. The amount needed for a more challenging implosion-type bomb is less; the Nagasaki bomb, for example, used some 6 kilograms of plutonium (the amount of HEU required for a similar design would be roughly three times larger); that amount of plutonium is about the size of a soda can.[62] In either case, the material for a nuclear bomb could fit in a suitcase. A nuclear bomb could easily be transported across borders in already-manufactured parts that would be small and easy to hide, but which could be assembled in a matter of hours at the target. Even a fully assembled bomb of the crude type terrorists might make could fit in a truck, a fishing boat, a small plane, or the hold of a yacht.

Moreover, the radioactivity from these materials is weak and difficult to detect from any substantial distance.[63] The year after Hiroshima, J. Robert Oppenheimer, the leader of the Manhattan Project, testified to Congress that it would be easy for a small team to destroy an American city by smuggling in a nuclear bomb. Asked how packages coming into a city could be checked to see if they contained a nuclear bomb, Oppenheimer replied that his "most important tool would be a screwdriver."[64] Two scientists were later given the job of examining the options for nuclear detection, and wrote a classified study often called "the screwdriver report," outlining the very limited options for detecting nuclear material. Wolfgang K.H. Panofsky, one of that report's authors, emphasizes that today, although radiation detectors have "improved enormously," the "physics hasn't changed. You still can't detect a nuclear device unless you are close to it. We are wasting an enormous amount of money in the United States by building better and better detec-

[60] For useful discussions, see Allison, *Nuclear Terrorism: The Ultimate Preventable Catastrophe*; Anthony Wier, "Interdicting Nuclear Smuggling," in *Nuclear Threat Initiative Research Library: Securing the Bomb* (Cambridge, Mass., and Washington, D.C.: Project on Managing the Atom, Harvard University, and Nuclear Threat Initiative, 2002; available at http://www.nti.org/e_research/cnwm/interdicting/index.asp as of 25 July 2007).

[61] See, for example, Rensselaer Lee, *Nuclear Smuggling and International Terrorism: Issues and Options for U.S. Policy*, RL31539 (Washington, D.C.: Congressional Research Service, 2002).

[62] For discussion, see John P. Holdren and Matthew Bunn, "Technical Background: A Tutorial on Nuclear Weapons and Nuclear-Explosive Materials," in *Nuclear Threat Initiative Research Library: Securing the Bomb* (Cambridge, Mass., and Washington, D.C.: Project on Managing the Atom, Harvard University, and Nuclear Threat Initiative, 2002; available at http://www.nti.org/e_research/cnwm/overview/technical.asp as of 07 August 2007).

[63] For discussion, see Holdren and Bunn, "Technical Background: A Tutorial on Nuclear Weapons and Nuclear-Explosive Materials."

[64] The text of this passage is quote in Alex Kingsbury, "History's Troubling Lessons," *U.S. News and World Report* (26 February 2007; available at http://www.usnews.com/usnews/news/articles/070218/26nuclear.b.htm as of 17 May 2007).

tors, but the basic physics puts very severe limits on what you can do." Panofsky likens the problem to the old story of how to catch a rabbit: "In order to catch a rabbit you have to put salt on its tail, but while you are trying to do that you first have to catch the rabbit. It's the same with nuclear terrorism."[65]

Plutonium is much "brighter"—more radioactive—than HEU, and emits both gamma rays and neutrons, making it easier to detect with passive detectors. Radiation detectors that detect both gamma rays and neutrons would have a reasonable chance of detecting plutonium (or most materials for a radiological "dirty bomb") in a car or shipping container that passed through the detector (unless it was well shielded), but they would have essentially no chance of detecting "clean" HEU with even modest shielding.[66] HEU which was produced from irradiated uranium, however (including most Russian HEU) is contaminated with U-232, which decays to an isotope that releases more penetrating gamma rays, making such HEU significantly easier to detect. Even the expensive new Advanced Spectroscopic Portals now being developed would not substantially improve the ability to detect shielded HEU, though they would greatly improve the detectors' ability to tell the difference between plutonium or dirty-bomb material and naturally radioactive materials, from kitty litter to granite to bananas. (Today, there are roughly 1,000 false alarms from radiation detectors in the United States alone in an average day.) Technologies such as active nuclear detectors (which probe the items they are searching with beams of radiation) and combining nuclear detection with X-rays to detect shielding may help, but pose their own problems and difficulties.[67]

Beyond the physics problems, there are the human nature problems: on a daily basis across the globe, smugglers bribe border patrol or customs officials to look the other way as a variety of contraband passes through. A variety of approaches can limit this risk—for example, many radiation detectors have their signal sent not only to the official on-site at the border crossing, but to another station some distance away, making it more difficult to bribe the border guard to let a shipment pass. But the issue of corruption and the wide range of adversary options for defeating such systems remains fundamental.

Furthermore, even when border agents have adequate and specific warning about a possible threat, they can overlook the target among the steady stream of traffic they must cope with. In one recent

[65] Michael Schaaf and Hartwig Spitzer, ""Immediately after the Explosion I Fell Asleep": An Interview with Wolfgang Panofsky" (Hamburg: Center for Science and International Security, University of Hamburg, 6 July 2006; available at http://censis.informatik.uni-hamburg.de/publications/Panofsky_Interview_M_Schaaf_6_Juli_2006_korr_13_Nov.pdf as of 09 July 2007).

[66] See, for example, discussion in Thomas Cochran, "An Assessment of the Detection of Highly Enriched Uranium and its Use in an Improvised Nuclear Device using the Monte Carlo Computer Code MCNP-5," presented at the American Physical Society April Meeting, Jacksonville, Florida, 14-17 April 2007. See also Committee on Homeland Security, Subcommittees on Prevention of Nuclear and Biological Attack and Emergency Preparedness, Science, and Technology, *Detecting Nuclear Weapons and Radiological Materials: How Effective Is Available Technology?* U.S. House of Representatives, 109th Congress, 1st Session, 21 June 2005; Steve Coll, "The Unthinkable: Can the United States Be Made Safe from Nuclear Terrorism?" *The New Yorker* 83, no. 3 (12 March 2007; available at http://www.newyorker.com/reporting/2007/03/12/070312fa_fact_coll as of 7 May 2007), pp. 48-57..

[67] For a discussion of passive vs. active detection approaches for nuclear material, see, for example, Brent K. Park et al., "Advances in Nuclear Monitoring," *Forum on Physics and Society* 35:3, July 2006 (available at http://units.aps.org/units/fps/newsletters/2006/july/article6.cfm as of 13 June 2007).

and revealing non-nuclear example, after a U.S. Customs and Border Protection inspector in Champlain, New York scanned the passport of tuberculosis carrier Andrew Speaker, a Center for Disease Control warning flashed on the inspector's computer that read, "Isolate. Detain. Call Public Health Services." Speaker's car was one of 2,674 passenger vehicles that passed through the Champlain crossing that day, and the warning was one of about 40 that required further investigation. The inspector, an 18-year veteran with significant training, determined on his own that Speaker did not appear ill and allowed his car to enter the United States.[68] In prepared Congressional testimony, the Department of Homeland Security claimed that while "the system functioned properly," there was "a single point of failure in this case—human error by an individual who may have failed to follow appropriate procedures."[69]

In any case, the obvious question is why a nuclear smuggler would bring his HEU or plutonium through an official border crossing with readily observable inspectors and radiation detectors in the first place. There are countless other opportunities for going uninspected across the wild borderlands of the world—including U.S. borders. In the United States, it remains perfectly legal to sail up the Hudson or the Potomac with an uninspected ocean-going yacht, to take just one example. Some scientists have envisioned getting around the problem of only looking at a few fixed and observable border points by deploying hundreds of thousands of next-generation detectors, some of them hard to notice and mobile, in cities and countries all over the world, at a cost of many billions of dollars; but whether the reduction in risk that would result would be worth the cost—even if countries around the world agreed to put such detector networks in place and succeeded in operating them effectively—remains hotly debated.[70]

Of course, radiation detectors are not the only tool available to interdict nuclear smuggling. Almost all of the known interdictions have, instead, resulted from good police or intelligence work—from sting operations, or from people who became aware of the conspiracy deciding to inform the authorities. There are a wide range of steps that can and should be taken to strengthen international police and intelligence cooperation, to pursue additional demand stings (posing as buyers of nuclear material or expertise) and supply stings (posing as sellers), and to encourage the semi-feudal chieftains who control some of the world's most dangerous borders to let us know about transports of nuclear material.[71]

[68] Spenser Hsu, "Breach Shows Borders Still Vulnerable," *Washington Post*, (11 June, 2007; available at http://www.washingtonpost.com/wp-dyn/content/article/2007/06/10/AR2007061001345_pf.html as of June 12, 2007); and ABC News, "TB Case Raises Border Security Questions," (2 June, 2007; available at http://abcnews.go.com/GMA/story?id=3238121 as of June 12, 2007).

[69] U.S. Department of Homeland Security Testimony, U.S. House of Representatives, Committee on Homeland Security, 110th Congress,(6 June, 2007; available at http://homeland.house.gov/SiteDocuments/20070606160915-56082.pdf as of 12 June 2007).

[70] Coll, "The Unthinkable: Can the United States Be Made Safe from Nuclear Terrorism?"

[71] See, for example, Rensselaer Lee, "Nuclear Smuggling: Patterns and Responses," *Parameters: U.S. Army War College Quarterly* (Spring 2003; available at http://carlisle-www.army.mil/usawc/Parameters/03spring/lee.pdf as of 09 July 2007). For an interesting account of the possibility of working with smuggling chieftains at foreign borders, see William Langewiesche, "How to Get a Nuclear Bomb," *Atlantic Monthly* 298, no. 5 (December 2006), pp. 80-98. Unfortunately, that article is otherwise marred by a variety of errors and misjudgments.

It is worth investing in improved border detection systems, to make the nuclear smuggler's job more difficult and uncertain. But this line of defense will inevitably be highly porous, and the world should not place undue reliance on it.

A Terrorist Nuclear Attack Would Be a Devastating Catastrophe

Finally, detonation of even a crude terrorist bomb in a major city would be a catastrophe of historic proportions. A bomb with the explosive power of 10,000 tons of TNT (that is, 10 "kilotons," somewhat smaller than the bomb that obliterated Hiroshima), if set off in mid-town Manhattan on a typical workday, could kill half a million people and cause more than $1 trillion in direct economic damage.[72] Neither the United States nor any other country in the world is remotely prepared to cope with the aftermath of such an attack—the need to care for tens of thousands of burned, wounded, and irradiated victims (far more than the entire country's supply of burn or radiation treatment beds), the need to evacuate hundreds of thousands of people in the path of the fallout, the enormous challenge of restoring essential services to a partly burned and irradiated city, and more.[73]

Devastating economic aftershocks would reverberate throughout the country and the world. Today's national and international economies are far more interdependent than they were when Hiroshima and Nagasaki were destroyed, spreading the impact far and wide. Fear of a possible second bomb would be immediate. Terrorists—either those who committed the attack or others—would be likely to claim they had more bombs already hidden in U.S. cities (whether they did or not), and the fear that this might be true could lead to panicked evacuations of major U.S. cities, creating widespread havoc and economic disruption.

Confidence in the national government would be profoundly shaken, as no one could be confident that the government that had failed to protect them from the

[72] See Matthew Bunn, Anthony Wier, and John Holdren, *Controlling Nuclear Warheads and Materials: A Report Card and Action Plan* (Cambridge, Mass., and Washington, D.C.: Project on Managing the Atom, Harvard University, and Nuclear Threat Initiative, 2003; available at http://www.nti.org/e_research/cnwm/cnwm.pdf as of 2 January 2007), pp. 15-19. This was a rough estimate based on a relatively crude analysis. A number of more detailed analyses of the effects of a terrorist nuclear weapon in a U.S. city are available, though a surprising number of them either envision a bomb going off in an area with much lower population density than mid-town Manhattan, or envision the bomb being detonated at night (when the populations at the center of most cities are far lower, but easier to get information about from the U.S. census). For a recent official government analysis of such an event in Washington D.C., see, for example, U.S. Homeland Security Council, *National Planning Scenarios: Version 20.1 Draft* (Washington, D.C.: U.S. Homeland Security Council, 2005; available at http://media.washingtonpost.com/wp-srv/nation/nationalsecurity/earlywarning/NationalPlanningScenariosApril2005.pdf as of 09 July 2007). Recent detailed non-government analyses include Ira Helfand, Lachlan Forrow, and Jaya Tiwari, "Nuclear Terrorism," *British Medical Journal* 324 (9 February 2002; available at http://www.bmj.com/cgi/reprint/324/7333/356.pdf as of 09 July 2007); Charles Meade and Roger C. Molander, *Considering the Effects of a Catastrophic Terrorist Attack* (Washington, D.C.: RAND, 2006; available at http://www.rand.org/pubs/technical_reports/2006/RAND_TR391.pdf as of 8 August 2007).

[73] Ashton B. Carter, Michael M. May, and William J. Perry, *The Day After: Action in the 24 Hours Following a Nuclear Blast in an American City*, a report based on a workshop hosted by the Preventive Defense Project (Cambridge, Mass. and Palo Alto, Cal., Harvard and Stanford Universities, Preventive Defense Project, May 2007; available at http://bcsia.ksg.harvard.edu/BCSIA_content/documents/DayAfterWorkshopReport_May2007.pdf as of 12 June 2007). For another useful recent account, see Ira Helfand et al., *The U.S. and Nuclear Terrorism: Still Dangerously Unprepared* (Washington, D.C.: Physicians for Social Responsibility, 2006; available at http://www.psr.org/site/DocServer/PSR_NuclearTerr_rpt_full.pdf?docID=781 as of 12 May 2007).

first attack would succeed in protecting them from another. Far more than after 9/11, U.S. policies on eavesdropping, searches, handling of terrorist suspects, and the legitimacy of attacking foreign countries to prevent possible future attacks on ourselves would change dramatically. America and the world would be transformed forever—and not for the better.[74]

Nor is nuclear terrorism only a threat to the United States. Al Qaeda or al Qaeda-inspired attacks intended to inflict mass casualties have occurred throughout the world. The Japanese terror cult Aum Shinrikyo, which launched a nerve gas attack in the Tokyo subways and attempted to build a nuclear bomb, was a wholly homegrown Japanese phenomenon—and such a group might sprout the next time in virtually any country. Moreover, even if the target was the United States, the effects would be global. Then-UN Secretary-General Kofi Annan estimated that the reverberating global economic effects of a nuclear terrorist attack would be sufficiently severe to push "tens of millions of people into dire poverty," creating "a second death toll throughout the developing world."[75] In short, insecure weapons-usable nuclear material anywhere is a threat to everyone, everywhere.

[74] For an argument that such an attack would leave the very notion of the sovereignty of nation-states in tatters, see Stephen D Krasner, "The Day After," *Foreign Policy*, no. 146 (January/February 2005), pp. 68-70.

[75] Kofi Annan, "A Global Strategy for Fighting Terrorism: Keynote Address to the Closing Plenary," in *The International Summit on Democracy, Terrorism and Security* (Madrid: Club de Madrid, 2005; available at http://english.safe-democracy.org/keynotes/a-global-strategy-for-fighting-terrorism.html as of 09 July 2007).

Nuclear Terrorism: Countering the Myths

Despite the facts just described, there are critics who argue that nuclear terrorism poses little real risk.[76] This belief, unfortunately, is often based on a number of myths which must be corrected.[77]

Some argue that terrorists want to draw attention to their cause and build support for their political objectives, rather than massacring huge numbers of people all at once. This is undoubtedly true of the vast majority of terrorist groups. But al Qaeda and some of its splinter groups have repeatedly made clear that they *do* want to escalate to the nuclear level of violence.[78] Al Qaeda spokesman Suleiman Abu Ghaith has argued that the group has the right to kill four million Americans, two million of them children, to retaliate for the deaths he believes America has caused in the Muslim world.[79]

[76] For a summary of these arguments, see Robin M. Frost, "Nuclear Terrorism after 9/11," *Adelphi Papers*, no. 378 (2005). and Karl-Heinz Kamp, "Nuclear Terrorism Is Not the Core Problem," *Survival* 40, no. 4 (Winter 1998); Ehud Sprinzak, "The Great Superterrorism Scare," *Foreign Policy* (Fall 1998; available at http://jya.com/superterror.htm as of 09 July 2007).

[77] For a more detailed rebuttal of these arguments (along with additional post-9/11 references doubting the threat) see Matthew Bunn and Anthony Wier, *Securing the Bomb: An Agenda for Action* (Cambridge, Mass., and Washington, D.C.: Project on Managing the Atom, Harvard University, and Nuclear Threat Initiative, 2004; available at http://www.nti.org/e_research/analysis_cnwmupdate_052404.pdf as of 2 January 2007), pp. 10-30.

[78] For a useful discussion, see Steve Coll, "What Bin Laden Sees in Hiroshima," *Washington Post*, 6 February 2005.

[79] "'Why We Fight America': Al-Qa'ida Spokesman Explains September 11 and Declares Intentions to Kill 4 Million Americans with Weapons of Mass Destruction," *MEMRI (Middle East Media Research Institute) Special Dispatch*, no. 388 (2002; available at

Some argue that it is simply inconceivable that terrorists could make a nuclear bomb, even if they obtained the needed nuclear material.[80] Former Director of Central Intelligence George Tenet reports that Pakistani President Musharraf made this argument, dismissing the threat of al Qaeda nuclear terrorism—and Musharraf has said much the same in public interviews as well.[81] It is true that getting nuclear materials and using them to make a nuclear bomb would be the most technically complex operation that any terrorist group has ever accomplished. But unfortunately, as described above, a relatively modest group, with no detectable fixed facilities and no access to classified information, might well be able to accomplish the job.[82] The possibility that terrorists could master the difficulties of making a nuclear bomb simply cannot be dismissed.

Others argue that there is virtually no chance that terrorists could get nuclear material.[83] This is undoubtedly a more difficult job than it has sometimes been made out to be; in particular, the record suggests that both Aum Shinrikyo and al Qaeda have had great difficulty making contact with genuine nuclear thieves, in a world of scams and intelligence sting operations.[84] But it is simply false to say that all the cases of stolen HEU and plutonium so far have represented "minor affairs of people caught filching or hawking scraps": there are multiple documented cases of theft of kilogram quantities of genuine weapons-usable nuclear material.[85] In one 1998 case, an insider conspiracy at one of Russia's nuclear weapons complex facilities attempted to steal 18.5 kilograms of HEU—potentially enough, depending on the enrichment, for an implosion-type bomb.[86] The other documented cases total to almost another 18 kilograms.[87] And of course, the fundamental question is: of what iceberg are these known cases the tip? In short, the probability of terrorists getting enough material for a nuclear bomb is certainly not as low as it should be, in the interests of world security.

Setting Priorities: Where the Nuclear Theft Risks are Greatest

In a world of limited resources—of both money and the time and attention of senior officials—it is critical to focus the resources devoted to improving nuclear security on those sites and transport legs where nuclear theft poses the greatest risks. The risk of nuclear theft at any par-

http://memri.org/bin/articles.cgi?Page=archives&Area=sd&ID=SP38802 as of 09 July 2007).

[80] Alexander Kotelnikov, deputy director of Rosatom for security, makes this argument in Aleksandr Khinshteyn, "Secret Materials," trans. BBC Monitoring Service, "Russian Central TV," 29 November 2002.

[81] Tenet, *At the Center of the Storm*, p. 266.

[82] See, for example, Bunn and Wier, "Terrorist Nuclear Weapon Construction"; Pluta and Zimmerman, "Nuclear Terrorism"; Zimmerman and Lewis, "The Bomb in the Backyard."

[83] Frost, "Nuclear Terrorism after 9/11"; Langewiesche, "How to Get a Nuclear Bomb."

[84] Bunn and Wier, "The Demand for Black Market Fissile Material."

[85] Frost, "Nuclear Terrorism after 9/11"; Langewiesche, "How to Get a Nuclear Bomb." p. 84.

[86] This case was first announced by the FSB in 1998. See Tkachenko, 1998, 18.5kilograms} Ministry of Atomic Energy official Victor Erastov provided somewhat more detail in a later interview "Interview: Victor Yerastov: Minatom Has All Conditions for Providing Safety and Security of Nuclear Material," *Yaderny Kontrol Digest* 5, no. 1 (Winter 2000). The fact that the material in question was HEU was confirmed to the author by a Ministry of Atomic Energy official, 2000.

[87] This is based on the incidents documented in the Database on Nuclear Smuggling, Theft, and Orphan Radiation Sources run by experts at the University of Salzburg, Austria. See International Institute for Strategic Studies, *Nuclear Black Markets* (London: IISS, May 2007), pp. 119-138.

ticular site or transport leg is determined primarily by the range of capabilities terrorists and thieves might be able to bring to bear to steal material in that country or region; how well the security system can protect the materials against adversaries with different kinds of abilities; and the quantity and quality of the nuclear material available to be stolen, which determines the chance that adversaries, once they had it, might be able to use it to make a crude but workable nuclear bomb.[88] If the stolen items are already assembled nuclear weapons, the probability that the adversaries could get a nuclear explosive capability out of them depends on the effectiveness of the weapons' built-in safeguards against unauthorized use, and on how much of what kinds of weapons-usable material the adversaries could get by cutting the weapon open.[89]

It may not always be the case that the sites with the weakest security pose the greatest risks, for some of these may be in countries where potential nuclear thieves have much less presence and ability to operate. A nuclear security system that might be good enough in Canada, for example, might be totally inadequate in Pakistan, where the threat is much higher.

Remarkably, it appears that neither the U.S. government nor the IAEA yet has a comprehensive, prioritized list assessing which facilities around the world pose the most serious risks of nuclear theft. Such a list would integrate assessments of the quantity and quality of material at each site (and therefore the chance that adversaries could make a nuclear bomb from it), the security at that site, and the level of capability adversaries might be able to bring to bear for a theft attempt in the area where the site exists.[90] Congress should consider instructing U.S. intelligence and operational agencies to work together to prepare such an integrated, prioritized assessment, and update it on a regular basis.

Based on the limited information publicly available, it appears that three areas or types of facility posing the highest risks of nuclear theft are Russia, Pakistan, and the HEU-fueled research reactors spread around the world. Each of these particularly high-priority cases is discussed in more detail below.

Nuclear Security in Russia—Yesterday and Today

As noted earlier, security for Russia's nuclear stockpiles has improved dramati-

[88] For a discussion, see Matthew Bunn, "A Mathematical Model of the Risk of Nuclear Terrorism," *Annals of the American Academy of Political and Social Science* 607 (September 2006). Certain aspects of what has been called the "environment" at the nuclear facility—such as whether large quantities of material are being processed by hand on a regular basis, at one extreme, or all the material is always locked in a vault to which almost no one has access, on the other extreme—also affect the probability of theft. See J.P. Hinton et al., *Proliferation Vulnerability Red Team Report*, SAND97-8203 (Albuquerque, N.M.: Sandia National Laboratories, 1996; available at http://www.osti.gov/bridge/servlets/purl/437625-gCUCGr/webviewable/437625.pdf as of 07 August 2007).

[89] Bunn and Wier, "Terrorist Nuclear Weapon Construction."

[90] The U.S. government has a variety of lists that include some pieces of this information, but no global list that integrates all the information needed for an overall risk assessment. The Global Threat Reduction Initiative (GTRI), for example, has a list of civilian HEU facilities (and some plutonium facilities) that includes estimates of the quantity and quality of material; rough ratings of security levels (based primarily on an assessment of whether sites do or do not comply with the IAEA physical protection recommendations); whether or not the sites are in high-income countries; and ratings of whether the sites are in high-threat, medium-threat, or low-threat countries. This is an important step in the right direction — but the U.S. government needs to build a prioritized list that assesses *all* of the sites and transport operations with nuclear weapons or weapons-usable nuclear material worldwide. (Data provided by DOE officials, July and August 2007.)

cally in the past 15 years. Nevertheless, there remain a number of reasons for serious concern:

- **Persistent underfunding of nuclear security.** The Russian government's investments in nuclear security remain far less than needed to meet the threat—and a as a result, reports of dilapidated security equipment and inadequate maintenance and inspection continue to be common. For example, in March 2005, the commander of the Ministry of Interior (MVD) troops for the Moscow district said that only seven of the critical guarded facilities in the district had adequately maintained security equipment, while 39 had "serious shortcomings" in their physical protection.[91] The head of Rosatom's physical protection firm, Eleron, publicly estimated in May 2005 that funding for physical protection covers only 30% of the need.[92]

- **Weaknesses in security culture.** Both Russian and American experts have reported a systemic problem of inadequate security culture at many sites—intrusion detectors turned off when the guards get annoyed by their false alarms, security doors left open, senior managers allowed to bypass security systems, effective procedures for operating the new security and accounting systems either not written or not followed, and the like.[93] The security chief at Seversk, a massive plutonium and HEU processing facility, reported that guards at his site routinely patrolled with no ammunition in their guns and had little understanding of the importance of what they were guarding.[94]

- **Weak nuclear security regulation.** As every dollar spent on security is a dollar not spent on activity that might bring in some revenue, nuclear managers will generally only invest in those security measures the government tells them they have to have. Hence, effective nuclear security rules, effectively enforced, are crucial to achieving high levels of security and sustaining them for the long haul. Nuclear security and accounting regulation in Russia has made some important strides in the past 15 years; in July 2007, after years of delay, the Russian government finally issued an updated overall

[91] See "Over 4,000 Trespassers Detained at Moscow District Restricted Access Facilities," *Interfax-Agentstvo Voyennykh Novostey*, 18 March 2005.

[92] Nikolai N. Shemigon, director-general, Eleron, remarks to Institute of Physics and Power Engineering, "Third Russian International Conference on Nuclear Material Protection, Control, and Accounting," Obninsk, Russia, 16-20 May 2005.

[93] Indeed, on one visit to a facility whose security had been upgraded with U.S. assistance, the U.S. General Accounting Office found that the gate to the central storage facility for the site's nuclear material was left wide open and unattended. At another site, guards did not respond when visitors entering the site set off the metal detectors, and the portal monitors to detect removal of nuclear material were not working. See U.S. Congress, General Accounting Office, *Nuclear Nonproliferation: Security of Russia's Nuclear Material Improving; Further Enhancements Needed*, GAO-01-312 (Washington, D.C.: GAO, 2001; available at http://www.gao.gov/new.items/d01312.pdf as of 2 January 2007), pp. 12-13. For a useful discussion of the security culture problem generally, see Igor Khripunov and James Holmes, eds., *Nuclear Security Culture: The Case of Russia* (Athens, Georgia: Center for International Trade and Security, The University of Georgia, 2004; available at http://www.uga.edu/cits/documents/pdf/Security%20Culture%20Report%2020041118.pdf as of 18 February 2005). See also Irina Kupriyanova, "Assessing the Effectiveness of the U.S. Nuclear Material Accounting, Control, and Physical Protection Program in Russia," *Yaderny Kontrol* 7, no. 2 (March/April 2002).

[94] Igor Goloskokov, "Refomirovanie Voisk MVD Po Okhrane Yadernikh Obektov Rossii (Reforming MVD Troops to Guard Russian Nuclear Facilities)," trans. Foreign Broadcast Information Service, *Yaderny Kontrol* 9, no. 4 (Winter 2003; available at http://www.pircenter.org/data/publications/yk4-2003.pdf as of 25 July 2007).

physical protection regulation.[95] But Russia's nuclear security rules still have important weaknesses, its regulatory agency has few resources for inspection and enforcement, and the regulators have far less power than Rosatom, the agency it is supposed to regulate. (DOE, however, has financed a new set of internal Rosatom inspections of physical protection and accounting at its own sites, which are a very important complement to external, independent regulation.[96]) The Ministry of Defense (MOD) unit with responsibility for regulating safety and security of nuclear weapons, MOD's other nuclear activities, and the weapons-production elements of Rosatom has even fewer resources available. Neither the MOD unit nor the civilian regulatory agency has authority to regulate the Ministry of Interior (MVD) guard forces that provide the primary security force for most non-MOD sites.

- **Problems with nuclear material accounting and control (MC&A).** Material control measures such as two-person rule, seals, portal monitors, keeping all material not in immediate use in secure vaults, and the like are crucial elements of the defense against insider threats; material accounting measures are key to determining whether or not a theft has occurred (and can deter insider thieves who would only steal nuclear material if the theft would not be noticed). Unfortunately, at many sites in Russia, key nuclear material control and accounting measures are either not in place or not consistently used. For example, at an international meeting in Russia in 2005, the Russian regulatory agency's top expert on MC&A detailed a wide range of inadequate control practices. He emphasized that even at sites with large numbers of modern U.S.-supplied tamper-indicating seals available, wax seals (translated by the interpreter as "Play-doh") that could be easily faked by any worker with a stamp were still in common use, because the sites were "too lazy" to use effective modern seals.[97]

- **Potentially ineffective nuclear guards.** Nuclear weapon sites in Russia are guarded by a well-trained, professional military force, the 12th Main Directorate of the Ministry of Defense (known as the 12th GUMO, its Russian acronym). At weapons-usable nuclear material sites, by contrast, the main response forces are young conscripts from the Ministry of Interior (MVD), who are often poorly paid and poorly trained.[98] The chief of security

[95]" "Procedures for the Physical Protection of Nuclear Material, Nuclear Facilities, and Nuclear Material Storage Points," Decree No. 456 (Moscow: Government of the Russian Federation, 19 July 2007).

[96] See, for example,Alexander Izmailov et al., "A Concept and Practical Aspects of Departmental Supervision of Rosatom Nuclear Facilities Physical Protection," in *Proceedings of the Third Russian International Conference on Nuclear Material Protection, Control, and Accounting, Obninsk, Russia, 16-20 May 2005* (Obninsk, Russia: Institute of Physics and Power Engineering, 2005).

[97] I.O. Khrokalo, speech to a plenary session at Institute of Physics and Power Engineering, "Third Russian International Conference on Nuclear Material Protection, Control, and Accounting." Through a U.S.-Russian Tamper-Indicating Device Working Group, DOE is working with Russia to improve Russian practices in the use of tamper-indicating seals, and in particular is seeking to convince Russian agencies to put in place rules that would require the use of modern tamper-resistant seals with unique serial numbers, which would be difficult to fake. Information provided by DOE, September 2007.

[98] A transition is underway toward greater use of the volunteer "Atomgard" force controlled by Rosatom, but so far Atomgard largely handles tasks internal to the sites, such as access control, and not the job of fighting off external adversaries. As one resident of Sarov put it to the author, "they are mostly old ladies, and they are not frightening." Personal communication, June 2006.

at Seversk reported that the Ministry of Interior troops guarding the facility routinely failed to protect the facility from outside attack in tests; routinely failed to prevent insiders from removing material in tests; often patrolled with no ammunition in their guns; and were frequently corrupt, becoming "the most dangerous internal violators."[99] The combination of low pay, boring work, and posting at remote nuclear sites contributes to low morale among these troops: brutal hazing and suicides are distressingly common.[100] The unit that guards Zheleznogorsk, a major plutonium production site, has become infamous for the number of suicides it suffers; a major MVD investigation in mid-2006 concluded that the problem was the "poor quality" of the draftees assigned to the unit, who included "alcoholics, sick and psychically misbalanced" conscripts, many of whom have been barred from carrying weapons.[101]

- **Endemic insider corruption.** Russia is afflicted with massive, systemic corruption. Of the states that have either nuclear weapons or significant amounts of high-quality weapons-usable materials, only Pakistan fares as poorly as Russia in Transparency International's ratings of corruption levels.[102] Corruption—from guards taking bribes to open gates, to managers taking bribes to hire new staff without checking their backgrounds—can open gaping holes in nuclear security systems. Unfortunately, the corruption endemic in Russian society has deeply penetrated the nuclear industry as well; former Minister of Atomic Energy Evgeniy Adamov's coruption trial is only the most visible symbol of this problem. Several former mayors of closed nuclear cities are on trial for corruption, and U.S. academic researchers, working with residents of the closed nuclear city of Ozersk, documented extensive corruption at the Mayak nuclear facility and organized crime activity in Ozersk.[103] In 2006, for example, Major General Sergey Shlyapuzhnikov, deputy chairman of the section of the MVD responsible for guarding closed territories (such as the closed nuclear cities), was relieved of his duties for helping to organize smuggling in and out of these closed territories—in particular, giving out passes that allowed people and their vehicles to enter and leave the territories without being checked.[104]

[99] Goloskokov, "Reforming MVD Troops to Guard Russian Nuclear Facilities [Translated]."

[100] "Analysis: Hazing in Russian Guard Units Threatens Nuclear Cities Security," *Foreign Broadcast Information Service*, 9 June 2005.

[101] "Mentally Impaired Join the Russian Army," *www.gazeta.ru*, 15 August 2006 (translated by Anatoly Dianov, DOE Moscow). See also Christian Lowe, "'Unstable Recruits' Guard Russia Nuclear Facility," 22 August 2006 (available at http://www.commondreams.org/headlines06/0822-02.htm as of 12 June 2007).

[102] In the ratings for 2006, Russia received a rating of 2.5 out of 10 (where higher ratings are better), putting it at 121 out of 165 countries ranked (with 165 being most corrupt); Pakistan, with a rating of 2.2, was ranked at 142. See Transparency International, *Corruption Perceptions Index 2006* (Berlin: TI, 2006; available at http://www.transparency.org/policy_research/surveys_indices/global/cpi as of 09 July 2007).

[103] For a short summary of this work, see Robert Orttung and Louise Shelley, *Linkages between Terrorist and Organized Crime Groups in Nuclear Smuggling: A Case Study of Chelyabinsk Oblast*, PONARS Policy Memo No. 392 (Washington, D.C.: 2005; available at http://www.csis.org/media/csis/pubs/pm_0392.pdf as of 10 July 2007). A more detailed report of this work by the same authors has not yet been published.

[104] The President Issued a Decree To Dismiss Deputy Chairman of the MVD Department in Charge of Law and Order in Closed Territories and Sensitive Sites, Major General Sergey Shlyapuzhnikov,"

- **Large-scale insider theft.** Not only does Russia suffer from a serious corruption problem, there is also a major problem of theft by insiders within a wide range of organizations—in some cases involving conspiracies of several insiders working together, a scenario that is among the most difficult for any nuclear security system to defeat. In 2006, it was revealed that a conspiracy of insiders had stolen hundreds of valuable items from the Hermitage, one of Russia's flagship—and most secure—museums.[105] Nuclear facilities are not immune from such insider thefts. In October 2004, sources in the local and regional Ministry of Internal Affairs reported that thieves had stolen three valves, valued at 700,000 rubles (over $20,000), from the Leningrad Nuclear Power Plant. The plant, like all Russian nuclear power plants, is protected by armed guards, leading police to assume that the theft was probably an inside job. Nor was this likely the first time such a theft has occurred: the head of the local branch of the Ministry of Internal Affairs told a reporter, "I don't know why this crime has attracted so much attention...such thefts happen here often."[106] In 2006, Colonel Yury Navrotsky was accused of stealing 14 tank cars of fuel from nuclear warhead facilities in Russia's Far East.[107] In the case of nuclear weapons and materials, the temptations for such insider theft may be high: in one case revealed in 2003, a Russian businessman was offering $750,000 for stolen weapon-grade plutonium for sale to a foreign client.[108]

- **Major terrorist attacks.** Nuclear facilities in Russia also face a serious threat from terrorists who have demonstrated the ability to strike in force, without warning or mercy. Few nuclear facilities in Russia (or elsewhere, for that matter) could defend against an attack on the scale of the Beslan school massacre in Russia in September 2004—32 suicidal terrorists, armed with machine guns, rocket-propelled grenades, and explosives, launching a carefully planned attack with no warning. Nor is that size of attack the upper limit: the Beslan attackers had acquired some of their weapons stockpile in a June 2004 raid on Russian Interior Ministry buildings and arms depots in the neighboring province of Ingushetia that involved at least 200 attackers and left some 80 people dead. In that raid, the attackers, dressed in uniforms of the Russian Federal Security Service, Army intelligence, and other special

Rossiyskaya Gazeta, 2 June 2006 [translated by Anatoly Dianov].

[105] Alex Rodriguez, "The Inside Job at Russia's Hermitage," *Chicago Tribune*, 20 August 2006; Geraldine Norman, "Mystery of Missing Treasures," *The Daily Telegraph (London)* 5 December 2006; and Galina Stolyarova, "State Has No Plan to Guard Works of Art," *Moscow Times*, 15 August 2006.

[106] Andrey Pankov, "S Atomnoy Elektrostantsii Vynesli Tri Dorogostoyashchikh Klapana (Three High-Priced Valves Carried Off from Nuclear Power Plant)," *Novyye Izvestiya*, October 2004. This article is translated and summarized in "Three Pinch Valves Were Stolen from the Leningrad Nuclear Power Plant, Abstract 20040380," in *Nuclear Threat Initiative Research Library: NIS Trafficking Database* (Monterey, Cal.: Monterey Institute for International Studies, Center for Nonproliferation Studies, 2004; available at http://www.nti.org/db/nistraff/2004/20040380.htm as of 25 July 2007).

[107] "Commanders Sell Fuel from Nuclear Facilities," *Kommersant*, 3 August 2006.

[108] For a summary of multiple Russian sources on this case, see "Plutonium Con Artists Sentenced in Russian Closed City of Sarov," *NIS Export Control Observer* (November 2003; available at http://cns.miis.edu/pubs/nisexcon/pdfs/ob_0311e.pdf as of 9 July 2007). See also "Russia: Criminals Indicted for Selling Mercury as Weapons-Grade Plutonium," trans. U.S. Department of Commerce, *Izvestiya*, 11 October 2003; "Russian Court Sentences Men for Weapons-Grade Plutonium Scam," trans. BBC Monitoring Service, *RIA Novosti*, 14 October 2003.

police squads, overwhelmed local forces, who did not receive reinforcements from federal security service troops for several hours.[109] (This is particularly distressing since the usual approach to security at nuclear facilities—including nuclear weapon storage sites—is to have a relatively modest defensive force on-site and to rely on reinforcements arriving in a timely way.) As already noted, senior Russian officials have confirmed that terrorist teams have carried out reconnaissance at Russian nuclear warhead storage sites. In late 2005, Russian Interior Minister Rashid Nurgaliev, in charge of the MVD troops guarding nuclear facilities, confirmed that in recent years "international terrorists have planned attacks against nuclear and power industry installations" intended to "seize nuclear materials and use them to build weapons of mass destruction for their own political ends."[110]

Civil society has a key role to play in nuclear security, but remains weak in Russia. Independent watchdogs in parliaments, in the press, and in non-government organizations can hold governments accountable for improving nuclear security. Revelations from outside the government have repeatedly contributed to nuclear security improvements in the United States. While the 1990s saw a considerable amount of bold reporting on these subjects in Russian publications such as *Yaderny Kontrol* (Nuclear Control), in recent years Russian civil society's role in nuclear security appears to have been very much weakened. (Like Russia, however, most other countries do not have the sort of non-government nuclear security watchdogs that exist in the United States.)[111]

In short, as a CIA report summed it up in 2006: "Russia's nuclear security has been slowly improving over the last several years, but we remain concerned about vulnerabilities to an insider who attempts unauthorized actions as well as to potential terrorist attacks."[112]

Security of Pakistan's Stockpile

Far less information is publicly available concerning security and accounting for nuclear material and nuclear weapons in Pakistan. As already noted, Pakistan has a relatively modest nuclear stockpile, which is thought to be distributed among only a small number of locations. Pakistan has sites where nuclear weapons exist (reportedly stored in partially disassembled form[113]) and sites with HEU or separated plutonium (particularly the main HEU production facility at Kahuta, but also including, among others, a research reactor with a small amount of U.S.-supplied HEU).[114] Pakistan's nuclear facilities are

[109] Mark Deich, "The Ingushetia Knot," *Moskovskii Komsomolets*, 6 August 2004; Boris Yamshanov, "Bribes Reeking of Explosives," *Rossiiskaya Gazeta*, 16 September 2004.

[110] "Internal Troops to Make Russian State Facilities Less Vulnerable to Terrorists."

[111] In the United States, such critiques have come from Congress, the press, and non-government organizations. One prominent example is the Project on Government Oversight. See, for example, Project on Government Oversight, U.S. Nuclear Weapons Complex: Y-12 and Oak Ridge National Laboratory at High Risk (Washington, D.C.: POGO, 2006; available at http://pogo.org/p/homeland/ho-061001-Y12.html as of 09 July 2007).

[112] U.S. National Intelligence Council, *Safety and Security of Russian Nuclear Facilities and Military Forces*.

[113] See, for example, Lee Feinstein et al., *A New Equation: U.S. Policy toward India and Pakistan after September 11* (Washington, D.C.: Carnegie Endowment for International Peace, 2002; available at http://www.carnegieendowment.org/files/wp27.pdf as of 09 July 2007). The chapter by Albright is of special interest.

[114] For a summary, see, for example, Joseph Cirincione, Jon B. Wolfsthal, and Miriam Rajkumar, *Deadly Arsenals: Nuclear Biological, and Chemical Threats*, 2nd ed. (Washington, D.C.: Carnegie

believed to be heavily guarded, though they probably are not equipped with state-of-the-art physical protection and material control and accounting technologies.[115]

If, as the Pakistani government claims, A.Q. Khan's exports of sensitive nuclear technology were completely unauthorized, then his activities over a 20-year period represent an immense security failure. In particular, entire centrifuges were removed from the Khan Research Laboratories—the centerpiece of Pakistan's nuclear weapons complex—and shipped off to foreign countries, in some cases in Pakistani military aircraft.[116]

Pakistani officials insist that they have taken a broad range of steps to beef up security and ensure that nothing comparable can ever happen again, but have offered virtually no specifics. Pakistan has reportedly established a security division headed by a two-star general under Pakistan's new Nuclear Command Authority; the division is reported to have 1,000 personnel (though this unit is to provide security against a broad range of threats, especially espionage, not just ensuring against theft of nuclear weapons and weapons-usable nuclear materials).[117] But Pakistan remains a society with a massive and deep-rooted problem of corruption, and this raises the same worrisome possibilities for short-circuiting security systems that exist in Russia.[118] While Pakistan reportedly now has extensive personnel screening and monitoring procedures in place,[119] it is unlikely that the nuclear enterprise can be entirely immune from the endemic problems facing the country.

Clearly, either state collapse or the rise of an extremist Islamic government in Pakistan—neither of which can by any means be ruled out—could pose severe dangers of nuclear assets becoming available to terrorists or hostile states. Even in the current environment, however, both insider and outsider threats to Pakistan's stockpiles appear to be dangerously high.

Insider threats. Recent events highlight the danger that insiders in Pakistan's nuclear complex, motivated by money, sympathy to extreme Islamic causes, or

Endowment for International Peace, 2005), pp. 239-258.

[115] The sparse information that is publicly available is summarized in Nathan Busch, *No End in Sight: The Continuing Menace of Nuclear Proliferation* (Lexington, KY: University Press of Kentucky, 2004). For a summary of the approaches Pakistan has taken to strengthen security and accounting (and command and control) for its nuclear assets since the A.Q. Khan network was revealed, see IISS, *Nuclear Black Markets*, pp. 112-117. See also Mahmud Ali Durrani, "Pakistan's Strategic Thinking and the Role of Nuclear Weapons" Cooperative Monitoring Center Occasional Paper 37 (Albuquerque, New Mexico, July 2004; available at http://www.cmc.sandia.gov/cmc-papers/sand2004-3375p. pdf as of 12 June 2007). For a summary of which institutions within Pakistan are responsible for each aspect of nuclear security and accounting, see Muhammad Afzal, "Cooperation in Fissile Material Management: The View from Pakistan," in *Proceedings of the 46th Annual Meeting of the Institute for Nuclear Materials Management, Phoenix, Ariz., 10-14 July 2005* (Northbrook, Ill.: INMM, 2005).

[116] A comprehensive description of the activities of the A.Q. Khan network can be found in IISS, *Nuclear Black Markets*.

[117] For a brief description of this unit, see IISS, *Nuclear Black Markets*, pp. 110-111. See also Peter Lavoy, "Pakistan's Nuclear Posture: Security and Survivability" (Washington, D.C.: Nonproliferation Policy Education Center, January 2007). As Lavoy points out, secrecy is extremely important to Pakistan's nuclear leadership, to ensure that no one knows the locations of the weapons so that they cannot be attacked.

[118] As noted earlier, Transparency International's most recent ratings put Pakistan among the most corrupt nations on earth. Transparency International, *Corruption Perceptions Index 2006*.

[119] IISS, *Nuclear Black Markets*, pp. 113-114.

both, might help terrorists get a bomb or bomb material from Pakistan's stockpiles. First, the A.Q. Khan network demonstrates the willingness of at least some nuclear insiders to sell practically anything to practically anyone—including not only centrifuges and related technologies but an apparently Chinese-origin nuclear bomb design.[120] Second, there is the remarkable case described earlier, in which Osama bin Laden and his deputy Ayman al-Zawahiri met at length with two senior Pakistani nuclear weapons experts with extreme Islamic views and pressed them both about nuclear weapons and about others in Pakistan's program who might be willing to help. Neither of these Pakistani scientists were ever tried or imprisoned, though it appears they remain under a loose form of house arrest. Bin Laden may have been on the right track in asking for others who could help: by one estimate from a Pakistani physicist, some 10% of Pakistan's nuclear insiders are inclined to extreme Islamic views.[121] Third, Pakistani investigations of the assassination attempts against President Musharraf in late 2003 suggest that they were carried out by military officers in league with al Qaeda operative Abu Faraj al-Libbi, raising the disturbing possibility that al Qaeda might also find people willing to cooperate among the officers charged with guarding nuclear stockpiles.[122] In short, the danger that insiders might pass material or weapons to al Qaeda, or facilitate an outsider attack, appears to be very real.

Outsider threats. Similarly, the threat from a possible terrorist attack on a Pakistani nuclear weapon depot appears dangerously high. Armed remnants of al Qaeda and of the Taliban continue to operate in the nearly lawless tribal zones on Pakistan's border with Afghanistan, and appear to be consolidating and strengthening their operations. Indeed, some combination of al Qaeda, Taliban, and Pakistani fighters were able to hold off thousands of Pakistani regular army troops for days at a time in a pitched battle in the tribal zones in early 2004.[123] If 41 heavily armed terrorists can strike without warning in the middle of Moscow, how many might appear at a Pakistani nuclear weapon storage site? Would the guards at the site be sufficient to hold them off—and would the guards choose to fight or to cooperate?

The Threat from Research Reactor Fuel

Some 60 metric tons of HEU—enough for over a thousand nuclear weapons—is in civilian use or storage throughout the world. Most of this is in the form of fuel for research reactors. As noted earlier, roughly 140 operating research reactors still use HEU as their fuel. In addition, an unknown number of the scores of research reactors that have shut down without ever converting to LEU still have HEU fuel onsite.[124] While a majority of these research

[120] IISS, *Nuclear Black Markets*, pp. 79-80.

[121] Elizabeth Neuffer, "A US Concern: Pakistan's Arsenal: Anti-American Mood Poses a Security Risk," *Boston Globe* 2002.

[122] "Escaped Musharraf Plotter Was Pakistan Air Force Man," *Agence France Presse*, 12 January 2005; "Musharraf Al-Qaeda Revelation Underlines Vulnerability: Analysts," *Agence France Presse*, 31 May 2004.

[123] See, for example, Afzal Khan, "Pakistan's Hunt for Al Qaeda in South Waziristan," *The Jamestown Foundation*, 22 April 2004 (available at http://www.jamestown.org/news_details.php?news_id=45 as of 25 July 2007).

[124] All but one of the reactors that have been fully converted to LEU fuel with U.S. help have had all of their HEU removed—and the HEU from the remaining one will be shipped soon. In general, DOE seeks to ensure that the HEU is removed from converted reactor sites soon after it has cooled enough to be safely packaged and shipped (which may take several years after discharge from the reactor, in

reactors are either in the United States or Russia, HEU-fueled reactors exist in some 40 countries.

Many of these facilities do not have enough HEU on-site for a bomb. But a DOE study estimated that there are 128 nuclear research reactors or associated facilities around the world with 20 kilograms of HEU or more—potentially enough for an implosion-type bomb.[125] Moreover, one cannot rule out the possibility of terrorists stealing material from more than one facility, each of which might have less than the amount required for a bomb; the possibility of simultaneous attacks is highlighted by the near-simultaneous al Qaeda bombings on the U.S. embassies in Kenya and Tanzania in 1998. The potential use of research reactor HEU in nuclear weapons is not just a hypothetical concern: Iraq, in its "crash program" to make one nuclear bomb as quickly as possible after its invasion of Kuwait, planned to use both fresh and irradiated HEU from its research reactors.[126]

Most civilian research reactors have very modest security. Some are located on university campuses, where providing serious security against terrorist attack would be virtually impossible—and where many of the operators are students, who cycle through frequently, making it extraordinarily difficult to provide serious checks of potential insider thieves. Many research reactors were built 30-40 years ago, in the heyday of nuclear energy; many have since fallen on hard times and have few resources to continue safe operation or to pay for substantial security measures. The research reactor in the Congo, attempting to operate in the midst of a civil war, at a facility so impoverished the reactor does not have a telephone, is emblematic of the broader problem (though its fuel is just below the 20% line that defines HEU): fuel stolen from that reactor turned up in the hands of the Italian mafia.[127]

Even in the United States, which has some of the most stringent nuclear security rules in the world for other facilities, Nuclear Regulatory Commission (NRC) security rules for research reactors are remarkably weak. Research reactors are exempted from the requirement that facilities with more than 5 kilograms of U-235 in HEU emitting less than 100 rads per hour at one meter must have sufficient armed guards, fences, and other security measures in place to defeat theft attempts by either an insider or groups of armed outside attackers.[128] HEU emitting more than 100 rads per hour at one meter is exempted from almost all NRC physical protection requirements.

At the reactor at the Massachusetts Institute of Technology (MIT), since 9/11, there have been 1-2 Cambridge police officers with side-arms on-site to provide security—though these are not required by NRC rules. (Prior to the 9/11 attacks, the facility had no armed guards on-site, relying on response from off-site campus police of-

some cases). Data provided by DOE, September 2007.

[125] U.S. Congress, *DOE Needs to Take Action to Further Reduce the Use of Weapons-Usable Uranium*, p. 28.

[126] For a detailed discussion based on the discoveries of the IAEA Iraq Action Team after the 1991 Gulf War, see Albright, Berkhout, and Walker, *Plutonium and Highly Enriched Uranium, 1996: World Inventories, Capabilities, and Policies*, pp. 344-349.

[127] For a discussion of this episode, see Daly, Parachini, and Rosenau, *Aum Shinrikyo, Al Qaeda, and the Kinshasa Reactor*.

[128] For a discussion, see, for example, Edwin Lyman and Alan Kuperman, "A Re-Evaluation of Physical Protection Standards for Irradiated HEU Fuel," in *The 24th International Meeting on Reduced Enrichment for Research and Test Reactors, Bariloche, Argentina, 5 November 2002* (Argonne, Ill.: Argonne National Laboratory, 2002; available at http://www.rertr.anl.gov/Web2002/index.html as of 07 August 2007).

ficers in the event of a problem.) In April 2004, the facility had 29.5 kilograms of HEU on-site, which, prior to irradiation, had been 93% enriched.[129] To be fair, the MIT reactor is an unusually high-power research reactor (5 MWt), making the irradiated fuel there particularly radioactive and difficult to steal—but this is not true of many other research reactors that have similar (or weaker) security approaches. In mid-2005 an investigation by *ABC News* documented conditions ranging from sleeping guards to security doors propped open with books at nearly all of the 26 U.S. university-based research reactors, including those with HEU.[130]

Given these security conditions, it would not be difficult for attackers to break in and remove large quantities of HEU from a research reactor, or for insiders to remove such material. Unlike the large and massive fuel assemblies used in nuclear power reactors, fuel for research reactors is typically in fuel elements that are small and easy to handle—typically less than a meter long, several centimeters across, and weighing a few kilograms. In most cases, a thief could easily put several fuel elements at a time into a backpack, to be carried out to a waiting vehicle.

In general, the HEU in these fuel elements would require some processing before it could be used in a bomb—but the kind of processing required is reasonably straightforward, and all the details of the necessary processes are published in the open literature. It is important to understand that the threat of nuclear theft at research reactors comes not only from the "fresh," unirradiated HEU fuel, but also from the irradiated fuel. Irradiated HEU fuel typically remains quite highly enriched; is much less radioactive than power reactor spent fuel (in many cases well below the 100 rad/hr level considered "self-protecting" against theft under international standards—a standard that should itself be reconsidered in the face of post-9/11 threats of suicidal attackers); and requires the same physical and chemical processing to recover HEU for use in a weapon as the fresh fuel elements require. Thus, *kilogram for kilogram, lightly irradiated research reactor fuel poses only a modestly lower proliferation danger than fresh research reactor fuel*—and there is far more irradiated HEU fuel at poorly secured reactor sites around the world than there is fresh fuel.[131] The danger posed by research reactor spent fuel stands in stark contrast to the modest theft threat posed by nuclear power reactor spent fuel assemblies, which are huge, heavy, and intensely radioactive, making them quite difficult to steal and process.

A Global Threat

The identification of these three categories as the highest priority threats is by no means intended to minimize the threats that exist elsewhere around the world. From large-scale transports of civilian plutonium that have been reported to

[129] Visit by the author, April 2004.

[130] "Radioactive Road Trip," "PrimeTime Live," *ABC News*, 13 October 2005.

[131] For a discussion of these stockpiles, see Iain G. Ritchie, "Growing Dimensions: Spent Fuel Management at Research Reactors," *IAEA Bulletin* 40, no. 1 (March 1998; available at http://www.iaea.org/Publications/Magazines/Bulletin/Bull401/article7.html as of 10 July 2007). Some analysts have pointed to the modest interest that commercial reprocessing firms have had in separating uranium from research reactor fuel to argue that such separations would be very difficult. But there is a huge difference between separating enough uranium to be of commercial interest and separating the much smaller amount needed for a bomb—and there is a huge difference between separations that meet all modern safety regulations and quick and dirty separations that might be done by terrorists.

have important security weaknesses,[132] to nuclear stockpiles in developing states such as China and India, the world faces a wide range of potential sources of nuclear theft.[133] There is probably no country where nuclear weapons and weapons-usable materials are located that does not have more to do to ensure that its nuclear stockpiles are secured and accounted for to a level sufficient to defeat demonstrated terrorist and criminal threats. Every nuclear weapon and every significant cache of potential bomb material, wherever it may be in the world, should at least be protected against a modest group of well-trained, well-armed outside attackers (capable of operating in more than one team), one to two well-placed insiders, or both together; in many countries, the plausible threats are greater, and security for such stocks should be correspondingly higher. This is a global problem, which can only be solved through a global campaign for nuclear security.

Progress, Obstacles, and Risks in the Past Year

The year since our last report has seen continued progress on a variety of fronts—most notably the launch of the Global Initiative to Combat Nuclear Terrorism—but also continued obstacles and new reminders of the deadly risk of nuclear terrorism. In particular, as already discussed, a wide range of events—from the seizure of stolen HEU in Georgia to the leader of al Qaeda in Iraq's call for nuclear scientists to join the jihad—make clear that nuclear theft and terrorism are continuing global dangers.

The Global Initiative to Combat Nuclear Terrorism

At their summit in July 2006, President Bush and President Putin announced the launch of the Global Initiative to Combat Nuclear Terrorism.[134] At the initiative's founding meeting, in Rabat, Morocco, in October 2006, the initial participants agreed on a very general statement of principles, including strengthening nuclear security and accounting, nuclear detection, legal frameworks focused on preventing nuclear terrorism, and emergency response capabilities.[135]

A second meeting was held in Ankara, Turkey, in February 2007, and a third in Kazakhstan in June 2007.[136] The initia-

[132] For a discussion of the frequency of large shipments of weapons-uable civilian plutonium now and in the future, see Albright, *Shipments of Weapons-Usable Plutonium*. For an analysis arguing that some of these shipments have inadequate security, see Timm, *Security Assessment Report for Plutonium Transport in France*.

[133] Given the highly controlled nature of North Korean society, theft of nuclear weapons or materials—as distinct from a conscious state decision to provide them to terrorists—appears quite unlikely as long as the current regime remains in power, though one could imagine a general deciding to sell off some material if he thought he could do so undetected. The North Korean collapse that some U.S. hardliners hope for, however, would create a dangerous problem of "loose nukes." See Ashton B. Carter, William J. Perry, and John M. Shalikashvili, "A Scary Thought: Loose Nukes in North Korea," *Wall Street Journal*, 6 February 2003.

[134] "Joint Statement by U.S. President George Bush and Russian Federation President V.V. Putin Announcing the Global Initiative to Combat Nuclear Terrorism" (St. Petersburg, Russia: The White House, Office of the Press Secretary, 15 July 2006; available at http://www.whitehouse.gov/news/releases/2006/07/20060715-2.html as of 09 July 2007).

[135] "Statement of Principles by Participants in the Global Initiative to Combat Nuclear Terrorism" (Washington, D.C.: The White House, Office of the Press Secretary, 31 October 2006; available at http://www.state.gov/r/pa/prs/ps/2006/75405.htm as of 09 July 2007).

[136] "Second Meeting of the Global Initiative to Combat Nuclear Terrorism, Joint Statement of the Co-Chairmen," (Ankara: February 12, 2007 available at http://www.state.gov/t/us/rm/80487.htm as of 12 June 2007).

tive participants have outlined a "Plan of Work" that includes a number of exercises and workshops designed to highlight the threat and help states strengthen their capabilities in the areas covered by the statement of principles.[137] The participants have set up a group, co-chaired by the United States and Russia, to review progress in implementing the initiative.[138]

The Global Initiative has the potential to be an important tool for convincing governments around the world that nuclear terrorism is a real and urgent threat, and focusing them on specific actions they can take to reduce the risk. The key challenges now are to move from general statements to concrete actions to improve nuclear security—including agreement on effective standards for nuclear security that all participants would agree to maintain and to help others to achieve. So far, in contrast to some other recent initiatives—such as on controlling terrorist financing—there are no particular standards to be met in order to be a participant in the Global Initiative, and no agreement that any participant's performance will be reviewed by other participants. Moreover, all the nuclear weapon states participating insisted that nuclear weapons and all military stockpiles of weapons-usable nuclear material—representing more than three-quarters of the world total—be kept out of the initiative entirely.

[137] The full plan of work is not publicly available, but it is emphasized in the statement from the initiative's second meeting. "Second Meeting of the Global Initiative to Combat Nuclear Terrorism, Joint Statement of the Co-Chairmen."

[138] U.S. Department of State, "Terms of Reference for Implementation and Assessment" (Washington, D.C.: November 20, 2006; available at http://www.state.gov/t/isn/rls/other/76421.htm as of 12 June 2007).

Progress in Security Upgrades and Sustainability in Russia

The past year saw continued progress in upgrading security at both nuclear warhead sites and weapons-usable nuclear material buildings in Russia, as both sides worked to finish, by the end of 2008, the plan agreed to after the Bratislava summit. As described in detail in the next chapter, by the end of fiscal year (FY) 2006, comprehensive upgrades had been completed for an estimated 55% of all the buildings with weapons-usable nuclear material in the former Soviet Union (63%, if only the buildings where the two sides have agreed on cooperative upgrades are counted), and security upgrades were completed at roughly half of the nuclear warhead sites in Russia (64% if only those sites on the agreed upgrade list are counted). Upgrades at 100% of the Russian Navy's nuclear warhead and weapons-usable nuclear material sites are now completed. While meeting the 2008 deadline remains a major challenge, it appears likely that the agreed upgrades will either be completed in 2008 or in the next year or two thereafter. As described in the next chapter, however, there are a significant number of weapons-usable nuclear material buildings and warhead sites where the United States and Russia have *not* yet agreed to cooperate on security upgrades; for those, the world will continue to rely on whatever security measures Russia has or will put in place with its own resources.

The agreement that DOE and Rosatom reached on sustainability for these upgraded security and accounting systems represents a major step forward.[139] The

[139] For DOE's release on this agreement, see U.S. Department of Energy, National Nuclear Security Administration, "U.S. & Russia Agree to Sustain Security Upgrades at Nuclear Material Facilities" (Washington, D.C.: DOE, 2007; available at http://

agreement reportedly includes a detailed listing of the remaining tasks to be done to achieve a sustainable security and accounting system at each site, and agreed list of which party will take responsibility for each task—with more and more of the tasks being Russia's responsibility as the effort moves toward the 2013 goal for a security system completely sustained with Russia's own resources.[140] The agreement covers Rosatom sites, but not the nuclear material sites controlled by other agencies or the nuclear warhead sites controlled by the Ministry of Defense. Site-level preparations for sustaining security upgrades are underway at these other locations, however, and NNSA Deputy Administrator for Defense Nuclear Nonproliferation William Tobey argued that "there's every reason to believe" that the agreement with Rosatom will pave the way for a similar, future agreement with the Ministry of Defense on nuclear warhead facilities. Top-level Russian commitment to providing the resources necessary to maintain effective security and accounting, and effective regulations, effectively enforced, are essential to ensuring that high levels of nuclear security are maintained for the long haul—and neither of those objectives is yet in clear view.

Post-Bratislava efforts have also led to a number of important initiatives to exchange "best practices" in a variety of key areas for nuclear security, and an expansion of joint efforts to promote strong security cultures—which will ultimately be crucial to achieving a nuclear security system that actually performs in protecting nuclear stockpiles from insider and outsider adversaries.[141] But these efforts remain at very early stages; how much effect they can have in strengthening the Russian nuclear security system, and whether they will be sustained after U.S. assistance phases out, remains an open question.[142]

Progress (and Remaining Gaps) on Nuclear Material Removals

The last year also saw an acceleration of progress in removing nuclear material from potentially vulnerable sites around the world, and in converting HEU-fueled research reactors to use low-enriched uranium. DOE's Global Threat Reduction Initiative (GTRI) helped ship 106 kilograms of HEU back to Russia in FY 2006, roughly four times the pace of the previous year. GTRI also brought 71 kilograms of HEU back to the United States under the U.S. take-back program, and removed another 83 kilograms of unneeded HEU from sites in Belgium, the Netherlands, and Canada in its "gap materials" program.[143] Moreover, GTRI helped convert five HEU-fueled research reactors to non-weapons-usable LEU during the year, and another just after the end of the fiscal

www.nnsa.doe.gov/docs/newsreleases/2007/PR_2007-04-11_NA-07-11.htm as of 21 May 2007).

[140] Interview with U.S. laboratory officials, January 2007.

[141] Several "best practices" discussions have been held; among other things, these have greatly expanded the dialogue between top Russian nuclear security officials and their counterparts responsible for security in the DOE complex. A more substantial dialogue on security culture has also developed, and additional sites are being added to the security culture coordinator program (including Seversk, one of the largest plutonium and HEU sites in Russia). Interview with U.S. laboratory officials, January 2007, and interview with DOE officials, December 2006.

[142] Chapter 2 provides a more detailed discussion of what aspects of other countries' nuclear security U.S. cooperative programs can most easily influence, and which are primarily up to foreign countries themselves.

[143] Data provided by DOE, August 2007. In February 2007, GTRI facilitated the removal of an additional 18.3 kilograms of HEU "gap" material from Canada (Chalk River), bringing the total cumulative amount of "gap" material removed to 101.7 kilograms.

year—two in the United States, two in Libya, one in the Czech Republic, and one in the Netherlands[144] — and helped beef up security to levels that met IAEA recommendations at one facility.[145] GTRI has already removed hundreds of kilograms of additional material, helped convert several additional reactors to LEU, and upgraded security at several HEU-fueled research reactors during fiscal 2007. In addition, GTRI expanded the list of reactors it hopes to convert to LEU (or, in a few cases, to much less enriched HEU) from 106 to 129, a significant step toward addressing the HEU-fueled reactors not covered by earlier conversion efforts.

Moreover, international discussions of minimizing the global use of HEU have accelerated in recent years. This is reflected, for example, in a Norwegian proposal at the 2005 Nonproliferation Treaty (NPT) review conference; a 2006 symposium in Oslo that reached broad technical agreement on the feasibility and desirability of converting the vast majority of HEU-fueled research reactors to LEU and called on the IAEA to continue to pursue conversion and HEU minimization; and agreement in 2007 that "minimizing the use of highly enriched uranium and plutonium in civilian facilities and activities" should be among the key priorities of the Global Initiative to Combat Nuclear Terrorism.[146]

But there is a very long road yet to travel—and significant gaps remain in current efforts to date. As described in detail in Chapter 2, only a small fraction of the HEU-fueled research reactor sites around the world have had all their HEU removed.

Even with its expanded scope, the conversion effort will only cover about 60% of the world's currently operating HEU-fueled reactors.[147] There is as yet no focused effort at DOE, the IAEA, or anywhere else to give research reactor operators and the countries that subsidize them incentives to shut unneeded and underutilized reactors and to allow scientists from those sites to be in user groups for more advanced reactors elsewhere (as is routinely done with accelerators in the high-energy physics community).

Of the roughly 17 tons of U.S.-origin HEU that was still abroad when the United States renewed its take-back offer in 1996, only 5.2 tons was eligible for the new offer—and GTRI currently plans to take back only a fraction of the eligible material.[148] GTRI does plan, however, to address

[144] Another HEU-fueled reactor in Germany shut down before conversion. Data provided by DOE, August 2007. See also National Nuclear Security Administration, "GTRI: More Than Three Years of Reducing Nuclear Threats," (Washington, D.C.: September 2007; available at http://www.nnsa.doe.gov/docs/factsheets/2007/NA-07-FS-03.pdf as of 11 September 2007).

[145] Data provided by DOE, March 2007.

[146] For discussions of the Oslo workshop and the earlier Norwegian initiative, see, for example, Christina Chuen and William C. Potter, "The Oslo Symposium: On the Road to HEU Minimization" (Monterey, Calif.: James Martin Center for Nonproliferation Studies, Monterey Institute for International Studies, 28 August 2007, available as of 10 September 2007 at http://cns.miis.edu/pubs/week/060822.htm). For the Global Initiative priority, see "Global Initiative to Combat Nuclear Terrorism: Joint Statement," Astana, Kazakhstan, 12 June 2007, available as of 10 September 2007 at http://www.state.gov/r/pa/prs/ps/2007/jun/86331.htm.

[147] Many HEU-fueled research reactors would be technically difficult or imposible to convert to LEU with currently known technologies; others are used for defense purposes, and GTRI does not expect to be able to convert most of those. The technical difficulties of converting many reactors are a key reason for an additional focus on giving unneeded reactors incentives to shut down.shutting down unneeded reactors.

[148] Data provided by DOE, July and August 2007. As discussed in detail in Chapter 2, some of the 17 tons of U.S.-origin HEU has been destroyed by ir-

almost a ton of additional material in its "gap" material program,[149] much of which appears to be U.S.-origin HEU not eligible for the original take-back.

But both of these efforts combined will cover only a small fraction of the U.S.-origin HEU that was abroad when the take-back effort began —though GTRI argues that it is focusing on the fraction of this HEU that poses the highest risks. Some of the material not covered is being reprocessed or otherwise addressed abroad, and some of it is at sites with highly effective security—but some of it is not. Similarly, it is not yet certain whether the "gap" material program or parallel efforts by other countries are effectively addressing the relatively limited amount of research reactor HEU that did not originate in either Russia or the United States or the small stocks of separated plutonium that exist at some research sites. Moreover, as of August 2007, some of the especially high-risk former Soviet sites, including sites in Belarus and Ukraine, had not yet agreed to give up their HEU stockpiles.

Limited Progress in Security Upgrades Elsewhere

DOE has made some progress working with other countries to upgrade nuclear security, but overall, the progress outside of the Soviet Union has been slow. The most extensive progress may be in Pakistan. Pakistan has now acknowledged that U.S.-Pakistani cooperation on improving nuclear security is underway (though insisting that U.S. personnel are not allowed access to sensitive information and are not allowed to visit the actual nuclear sites).[150] Both sides have kept the specifics of this cooperation classified, though some reports indicate that it has included providing a wide range of security equipment, training in matters such as vulnerability assessment, physical protection system design, and nuclear material accounting, and more.[151]

In China, one civilian site has had upgraded security and accounting systems installed, and there has been an extensive dialogue about modern approaches to nuclear material protection, control, and accounting. But as of October 2006, Chinese experts indicated that systems-engineering vulnerability assessments had not been performed at most sites, and were not required by Chinese regulations.[152] Cooperation on improving security for military nuclear assets in China has been blocked for years over obscure disputes over how to describe the record of U.S.-Chinese cooperation in these areas in the 1990s, and shows no sign of moving forward soon.[153] Cooperation to secure nuclear stockpiles went unmentioned in the nuclear agreement with India, and India has been rejecting DOE's suggestions to initiate such cooperation for years. Since the focus of discussions with North Korea is on eliminating its nuclear assets as soon as practical, no nuclear security discussions with North Korea are planned. The U.S. government presumes that Israel, with its long experience defending against terrorists, already has effective security in place for its nuclear assets. There are regular

radiation or reprocessed and recovered as LEU, but most has not.

[149] Data provided by DOE, March 2007.

[150] See, for example, Nirupama Subramanian, "Pakistan Accepted U.S. Help on N-Plants," *The Hindu*, 22 June 2006 (available at http://www.thehindu.com/2006/06/22/stories/2006062205201400.htm as of 09 July 2007).

[151] IISS, *Nuclear Black Markets*, p. 114.

[152] Interviews with Chinese physical protection experts, October 2006.

[153] Interview with retired DOE official, May 2007.

U.S.-British and U.S.-French discussions related to nuclear security matters, but these do not appear to be focused on major upgrades.

As described in detail in Chapter 2, most of the relatively modest number of HEU-fueled research reactors in the world which were judged not to have security that met IAEA recommendations have been upgraded so that they now follow those recommendations—but few have had more extensive security upgrades targeted on defeating demonstrated terrorist and criminal threats (both outsider and insider).

Little Progress Toward Stronger Global Nuclear Security Standards

Today, while there are a variety of agreements or resolutions that call for countries to take "appropriate" or "effective" measures to secure and account for their nuclear stockpiles, there are no specific and binding global standards for how secure nuclear weapons and the materials needed to make them should be. The levels of security provided for these stockpiles are largely left up to the whims of individual countries, despite the threat that insecure nuclear stockpiles in any one country pose to the entire world.

Very little progress has been made toward forging effective global standards in the past year. The most important positive step, perhaps, has been the beginning of international discussion (at least within a small group of like-minded countries) of a revision designed to strengthen the IAEA's physical protection recommendations—which were last revised in 1999, long before the 9/11 attacks. In addition, the United Nations Security Council (UNSC) approved a new resolution—1673—extending the life of the committee to oversee implementation of UNSC Resolution 1540, which legally requires every country with nuclear weapons or materials to provide "appropriate effective" security for them; the new resolution also called on states to provide assistance to other countries in meeting their UNSC 1540 obligations.[154] Unfortunately, UNSC 1540 remains an under-utilized tool: no one has yet defined what the essential elements of an "appropriate effective" nuclear security and accounting system are, and begun to pressure (and to help) countries to put those essential elements in place.

A small group of countries has begun discussing a potential revision of the IAEA physical protection recommendations, in preparation for formal discussions in an IAEA forum that are expected to begin soon. As discussed in Chapter 3, such a revision has the potential to have a major influence on improving nuclear security practices around the world.

In parallel with these efforts, additional countries have been signing the recent amendment to the physical protection convention and the new nuclear terrorism convention (though the number of states that have actually ratified is growing more slowly). While neither of these creates any specific global nuclear security standards, they each will provide some benefit in reducing the dangers of nuclear terrorism, and it is important for all states to sign, ratify, and implement them.[155]

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[154] UN Security Council, "Resolution 1673 (2006)," (New York: April 27, 2006; available at http://daccessdds.un.org/doc/UNDOC/GEN/N06/331/10/PDF/N0633110.pdf?OpenElement as of 12 June 2007).

[155] For the full text of the agreed amendment to the physical protection convention, see *Amendment to the Convention on the Physical Protection of Nuclear Material*. For the current list of eleven states that have ratified the agreement, see IAEA, "Amendment to the Convention on the Physical Protection of Nuclear Material," (Vienna: last change of status 1 August 2007; available at http://www.iaea.org/Publications/Documents/Conventions/cppnm_

Little Attention to Nuclear Security from the Global Partnership

When the Group of Eight (G8) industrial democracies announced the Global Partnership Against the Spread of Weapons and Materials of Mass Destruction in 2002, all the parties committed to provide effective security and accounting for their own nuclear stockpiles and to help others do the same.[156] The Global Partnership has been successful in drawing other countries into threat reduction activities and bringing some additional funding to the table. But of the billions of dollars of non-U.S. funds that have been allocated to the effort, only a few tens of millions of dollars have in fact been allocated to improving security for nuclear stockpiles.[157] Instead, most of the funds have gone to Russia's top priorities, dismantling submarines and destroying chemical weapons. At the 2007 G8 summit in Heiligendamm, like the 2006 summit before it, nuclear security was mentioned but got little attention. At Heiligendamm, the leaders did agree on a new approach to the Global Partnership that has the potential to be very important (though how much real impact it will have remains an open question). In addition to the work in Russia, they agreed to focus in the future on helping states implement the physical protection convention, the nuclear terrorism convention, UNSC 1540, full-scope safeguards, and the like, emphasizing that the goal was "a high level of global security," which could be achieved by "strengthening the weakest links."[158] In other words, without saying so explicitly, they effectively agreed that strengthening nuclear security around the world, not just in Russia or other designated recipient states, was a legitimate Global Partnership activity.

Increasing North Korean and Iranian Capabilities

As discussed earlier, conscious state decisions to transfer nuclear weapons and materials to terrorists are probably only a small part of the overall risk of nuclear terrorism. But however low the risk of state transfer is, it got notably worse during 2006, as both North Korea and Iran's capabilities expanded. (Unlike North Korea, however, Iran, as far as is known, still has not produced any weapons-usable nuclear material, and so has no such material available to transfer even if it chose to do so—except for a few kilograms of irradiated HEU the United States provided for the Tehran Research Reactor in the Shah's time.[159])

amend_status.pdf as of 10 September 2007). For the full text of the nuclear terrorism convention, see *International Convention for the Suppression of Acts of Nuclear Terrorism*. For the convention's status (along with that of other terrorism conventions) see U.S. Department of State, *Country Reports on Terrorism*, "International Convention and Protocols on Terrorism," (Washington, D.C.: April 30, 2007; available at http://www.state.gov/s/ct/rls/crt/2006/83238.htm as of 12 June 2007).

[156] "The G8 Global Partnership against the Spread of Weapons and Materials of Mass Destruction" (Kananaskis, Canada: Government of Canada, 27 June 2002; available at http://www.g7.utoronto.ca/summit/2002kananaskis/arms.html as of 09 July 2007).

[157] G8, Global Partnership Working Group, *GPWG Annual Report 2007, Consolidated Report Data, Annex A* (Heiligendamm, 6 June 2007; available at http://www.g-8.de/nsc_true/Content/EN/Artikel/_g8-summit/anlagen/gp-report-annex, templateId=raw, property=publicationFile.pdf/gp-report-annex as of 12 June 2007)

[158] G8, "Global Partnership Review" (Heiligendamm, 6 June 2007; available at http://www.g-8.de/nsc_true/Content/EN/Artikel/_g8-summit/anlagen/gp-report-annex, templateId=raw, property=publicationFile.pdf/gp-review-final as of 12 June 2007).

[159] This research reactor has since been converted to run on LEU, with help from Argentina (since no help was available from the United States after the 1979 revolution).

The North Korean nuclear test in October 2006, following the North Korean reprocessing of enough plutonium for a half a dozen nuclear bombs, was a dramatic set-back for U.S. and international security, reducing the probability of success in convincing North Korea to give up all of its nuclear weapons, materials, and ambitions. The test came after years of neglect by much of the Bush administration as the North Koreans stepped across almost every "red line" that had previously been drawn. The July 2007 shutdown of the North Korean plutonium production reactor should limit further increases in this risk; the danger that the North Korean government—or a clique within the ruling elite, without authorization from others—might decide to transfer nuclear weapons or material to terrorists is presumably smaller if only a limited and fixed stock of plutonium is available than it would be if North Korea already had more than it needed for its own deterrent and was steadily churning out more. But some 6-10 bombs' worth of plutonium remain in North Korea, the status of the North's suspected covert HEU program remains unknown, and the months of disputes that followed the February 2007 accord on first steps make clear that the road to denuclearization will be a long and bumpy one.[160]

Similarly, in the year since the last report, the United States has succeeded in sustaining an international coalition to oppose Iran's uranium enrichment progress, and the UN Security Council has repeatedly legally required Iran to suspend its enrichment and reprocessing activities. But Iran has ignored these Security Council resolutions, refused to consider the idea of suspending its enrichment activities (which the United States has made a condition for negotiations) and made substantial progress in putting in place many hundreds of uranium enrichment centrifuges and learning how to operate them, bringing closer the possible future day when Iran might be able to produce HEU. Efforts to restart negotiations with Iran on the nuclear issue have so far gone nowhere, as the United States and its European partners have insisted that that they will not negotiate until Iran suspends its enrichment activity and Iran has refused to suspend that activity again.

The Need for Action

Nuclear terrorism is a danger to every citizen of every country on earth. No one knows for sure how big the risk is. Well-informed analysts have made estimates of the probability of a terrorist attack with a nuclear explosive that range from 1% to over 50% over the next decade.[161] But

[160] With the cutoff of assistance from the Khan network, it appears unlikely that North Korea will be able to master the complex technology of centrifuge enrichment and produce significant amounts of HEU in the near term. North Korea does have several tens of kilograms of HEU in research reactor fuel, supplied by the Soviet Union decades ago. See, for example, Albright and Kramer, "Civil HEU Watch."

[161] Both Graham Allison and former Secretary of Defense William Perry have put the probability of a terrorist nuclear attack within the next decade at about 50 percent. See Allison, *Nuclear Terrorism: The Ultimate Preventable Catastrophe*; Nicholas D. Kristof, "An American Hiroshima," *New York Times*, 11 August 2004. By contrast, David Albright, who has written some of the most detailed unclassified analyses of seized al Qaeda nuclear documents, puts the ten-year probability in the range of 1%. See Corine Hegland and Gregg Webb, "The Threat," *National Journal* 37, no. 16 (15 April 2005; available at http://nationaljournal.com/about/njweekly/stories/2005/0415nj1.htm as of 09 July 2007). For a poll of leading national security and foreign policy experts on this and related points, see Richard G. Lugar, *The Lugar Survey on Proliferation Threats and Responses* (Washington, D.C.: Office of Senator Lugar, 2005; available at http://lugar.senate.gov/reports/NPSurvey.pdf as of 09 July 2007). For a mathematical model of the risk of nuclear terrorism, in which plausible estimates of the values of the input parameters lead to a 10-year probability estimate of 29%, see Bunn, "A Mathematical Model." As each of the input parameters

given the catastrophic potential consequences, even a 1% probability of nuclear terrorism over the next decade is enough to justify immediate action to reduce the risk. No one in his or her right mind would operate a nuclear power plant upwind of a major city if the chance of it blowing sky-high were as much as one in a thousand per year: it would be agreed by all that this risk was too high. Yet the risk the world is taking by operating the global nuclear security system as it exists today appears to be higher still.

This is not just an overblown American fear, as some have argued;[162] Mohammed ElBaradei, for example, the Director-General of the International Atomic Energy Agency (IAEA) has gone so far as to warn that the world is in "a race against time" to prevent nuclear terrorism—in essence, a race to lock down nuclear stockpiles around the world before terrorists and thieves can get to them.[163] Similarly, then-UN Secretary General Annan also warned of the danger, saying that the possibility of terrorists armed with nuclear weapons is not "science fiction. I wish it were."[164] Indeed, many analysts believe that the probability of terrorist use of nuclear weapons over the next decade is substantially higher than the probability of use of nuclear weapons by states.[165]

The need for further action is clear. But accomplishing the needed steps will not be an easy task. Dozens of programs working on different parts of reducing this risk have already been established in the United States and in other countries or international organizations, and these efforts have made very important progress, plucking nearly all of the low-hanging fruit. The next steps will be harder. In most cases, simply doubling or tripling the budgets for programs to secure nuclear stockpiles or inderdict nuclear smuggling, without solving any of the other obstacles these efforts face, would do little to accelerate progress (though there are a few important exceptions, as discussed later in this report).

In most cases, the steps that need to be taken now will require overcoming long-standing political and bureaucratic obstacles to progress—barriers that include complacency about the threat among policymakers and nuclear managers around the world, the extraordinary secrecy surrounding nuclear security in many countries, states' desire to maintain complete sovereign control over their security measures without outside interference, and nuclear managers' reluctance to invest precious time and resources in additional security measures.

The most important single goal must be to convince political leaders and nuclear managers around the world that nuclear terrorism is a real and urgent threat to *their* countries' security, worthy of a substantial investment of their time and resources to reduce the danger. Unless they are genuinely convinced of this, they

is highly uncertain, however, this estimate is also highly uncertain.

[162] For a particularly forceful statement of this dismissive view, see Kamp, "Nuclear Terrorism Is Not the Core Problem." For a debunking of a series of myths that lead analysts and policymakers to unduly downplay the risk of nuclear terrorism, see Matthew Bunn and Anthony Wier, "Debunking Seven Myths of Nuclear Terrorism and Nuclear Theft," in *Securing the Bomb: An Agenda for Action* (Cambridge, Mass., and Washington, D.C.: Project on Managing the Atom, Harvard University, and Nuclear Threat Initiative, 2004; available at http://www.nti.org/e_research/cnwm/overview/2004report.asp as of 2 January 2007).

[163] "Race against Time to Prevent Nuclear Terror—IAEA," *Reuters*, 8 November 2004.

[164] Annan, "A Global Strategy for Fighting Terrorism: Keynote Address to the Closing Plenary."

[165] See, for example, Lugar, *The Lugar Survey on Proliferation Threats and Responses*. (Washington, D.C.: June 2005; available at http://lugar.senate.gov/reports/NPSurvey.pdf as of 12 June 2007), p. 15.

will not take the political risks of opening sensitive sites to nuclear security cooperation, give their nuclear regulators the mission and power to enforce effective nuclear security rules, or provide the resources necessary to sustain high levels of security for the long haul. Many of these leaders are not convinced of this today. Pakistani President Pervez Musharraf, for example, has dismissed the danger of nuclear terrorism both in public and in private, and many Russian officials have said the same.[166] This report will outline a variety of steps—from detailed threat briefings to nuclear terrorism simulations to helping countries conduct their own realistic spot inspections of nuclear security at their sites—to try to get leaders around the world to understand the danger.

Building a consensus for action and overcoming the obstacles in the path will require sustained leadership, day-in and day-out, from the highest levels of government. The fact that progress in securing stockpiles in Russia has accelerated substantially after the Bush-Putin nuclear security accord at the Bratislava summit in early 2005 shows what presidential leadership can do. But the facts that some sites are still not covered by these efforts; that Russia continues to refuse to consider converting its research reactors from using HEU fuel, that Russia continues to guard its nuclear facilities with poorly paid and poorly trained conscript guards who have high rates of corruption and suicide; and that Russia's commitment to provide the resources to ensure effective security after U.S. assistance phases out remains very much in doubt; highlight the need for sustained, focused leadership to overcome such barriers—not only in Russia but around the world.

[166] For a public statement of this view, see David Brunnstrom, "Interview-Dirty Bomb a Fear, Not Nuclear Terrorism-Musharraf," *Reuters News*, 14 April 2005.

Plan of the Report

This report provides an analysis of risks, an assessment of progress in key programs to address those risks, and a series of targeted recommendations to strengthen and accelerate these efforts. The next chapter provides an assessment of measures of progress of key nuclear security programs—along with an analysis of important but difficult-to-measure factors, and remaining gaps in these efforts. Chapter 3 then offers specific recommendations to secure nuclear stockpiles worldwide. Chapter 4 outlines recommendations for later layers of defense beyond securing nuclear stockpiles at their sources. Chapter 5 recommends key approaches for moving this agenda forward. Finally, an appendix assesses President Bush's fiscal 2008 budget proposals and makes suggestions to ensure that efforts to reduce nuclear terrorism risks have the funds they need for maximum progress.

2 SECURING NUCLEAR STOCKPILES: A PROGRESS UPDATE

The United States, other countries, and the International Atomic Energy Agency (IAEA) have a wide range of efforts under way to improve security for nuclear stockpiles around the world—including by removing nuclear material entirely from vulnerable sites when possible.

This chapter provides an overview of the progress of these efforts—focusing on those funded by the United States, which represent a very large fraction of the total of cooperative efforts to upgrade security for nuclear stockpiles around the world.[1] This overview makes clear that these efforts to reduce the threat of nuclear terrorism have had real, demonstrable successes, representing an excellent investment in American and world security. Enough nuclear material for thousands of nuclear weapons has been permanently destroyed. (Indeed, nearly half of the nuclear-generated electricity in the United States comes from blended-down highly enriched uranium (HEU) from dismantled Russian nuclear weapons.) Security for scores of vulnerable nuclear sites has been demonstrably improved, and the United States and Russia have set a joint objective of completing security and accounting upgrades for most nuclear warhead and weapons-usable nuclear material sites in Russia by the end of 2008, now only a short time away. In Russia at least, security and accounting upgrades have been completed for more than half of the buildings and bunkers where nuclear warheads or the materials needed to make them exist.

But as we rightly celebrate this important progress—and the hard work by hundreds of U.S., Russian, and international officials and experts that brought it about—it is important to remain focused on the parts of the job yet to be done. The men and women who have struggled to move these efforts forward deserve the world's praise—but they also deserve as clear an assessment as can be offered of the scope of the task still to come, and the obstacles that must be overcome to get the remaining work done.

As will be described below, that remaining work is substantial: U.S.-funded security upgrades have not yet been completed for well over a third of the buildings and bunkers where Russia's nuclear stockpiles are located. Only about a quarter of Russia's stockpile of bomb uranium has been destroyed. It will still be years before destruction of substantial quantities of U.S. and Russian excess bomb plutonium even begins. Much less than half of the HEU-fueled research reactors targeted for conversion to less dangerous low-enriched uranium fuel have been converted, and many of these sites still have security measures that would offer little protection against some of the threats that terrorists and criminals have shown they can pose. Much less than half of Russia's excess nuclear weapons experts have yet received self-supporting civilian jobs (as opposed to short-term subsidized grants). Beyond

[1] A variety of other countries have also contributed to programs to improve nuclear security around the world. On this particular subset of cooperative threat reduction, however, the collective contribution from all other countries represents only a tiny fraction of the U.S. investment; and the majority of sites that other countries have contributed to upgrading have also involved the United States, so an assessment focusing on the sites where the United States has played a part in the upgrades is reasonably comprehensive.

the former Soviet Union, cooperative security upgrades are only just beginning, leaving many sites dangerously vulnerable, and no effective, binding global nuclear security standards have yet been put in place. The obstacles to finishing this work—complacency, lack of belief in the threat, secrecy, political and bureaucratic barriers to cooperation, and more—are daunting.

It is impossible to directly measure the risk of nuclear theft and terrorism, and whether it is increasing or decreasing. Hence, all the measures of progress the U.S. government uses to track these efforts, and all the measures I discuss in this chapter, are intended only as approximate indicators of progress in addressing one part of this multi-faceted problem. The metrics used here are inevitably rough summaries of a more complex story—and as discussed in detail below, progress toward some of the most important goals is very difficult to boil down into numerical metrics.

In the absence of hard data on the real effectiveness of nuclear security systems in the former Soviet Union and around the world, I rely, in this section, on metrics very similar (in most cases) to those the U.S. government uses to report the progress of its efforts in these areas. These focus, in particular, on (a) materials or buildings that have two defined levels of security and accounting equipment upgrades installed with U.S. assistance—"rapid" upgrades and "comprehensive" upgrades—and (b) buildings or sites where the potential nuclear bomb material has been removed entirely, eliminating the theft risk from that location.[2]

I have relied on official government measures and data where possible, but in some cases these are not available. The administration, led by the Department of Energy (DOE), has improved the availability and transparency of measures of performance for its programs to control nuclear warheads, materials, and expertise worldwide.[3] But the fact remains that the U.S. government has no comprehensive plan for ensuring that *all* nuclear weapons and weapons-usable materials worldwide are secure and accounted for, or for the other elements of a comprehensive approach to preventing nuclear terrorism, and has not put forward a complete set of milestones that would allow the Congress and the public to fully understand both how much progress is being made and where prolonged delays suggest the need for a change in approach.[4] Until that occurs, there remains an important role for

[2] Rapid upgrades include items such as installing nuclear material detectors at the doors, putting material in steel cages that would take a considerable time to cut through, bricking over windows, and counting how many items of nuclear material are present. "Comprehensive" upgrades represent the installation of complete modern security and accounting systems, designed to be able to protect the facility against at least modest insider and outsider theft threats.

[3] The detailed justifications of their budget proposals supplied by the agencies to the Congress contain performance information and targets for each major activity; see, for example, U.S. Department of Energy, *FY 2008 Congressional Budget Request: National Nuclear Security Administration* (Washington, D.C.: DOE, 2007; available at http://www.cfo.doe.gov/budget/08budget/Content/Volumes/Vol_1_NNSA.pdf as of 10 July 2007). The departments also publish assessments of their own performance, which often contain additional data. See, for example, U.S. Department of Energy, *Performance and Accountability Report: FY 2006*, DOE/CF-0012 (Washington, D.C.: DOE, 2007; available at http://www.cfo.doe.gov/progliaison/2006finalpar2.pdf as of 29 July 2007). Many programs have also been examined using the White House Office of Management and Budget's Program Assessment Rating Tool (PART); results of those assessments are available at http://www.expectmore.gov.

[4] For a discussion on the absence of a government-wide strategic plan, see U.S. Congress, Government Accountability Office, *Weapons of Mass Destruction: Nonproliferation Programs Need Better Integration*, GAO-05-157 (Washington, D.C.: GAO, 2005; available at http://www.gao.gov/new.items/d05157.pdf as of 10 July 2007), pp. 8-17.

reports such as this one, which attempt to provide the best progress assessments practicable from outside the government.

The progress measures in this report cover the period through the end of fiscal year (FY) 2006, the most recent year for which complete data are available. During FY 2007, however, additional nuclear material buildings and warhead sites have had nuclear security and accounting upgrades installed, several more HEU-fueled reactors have been converted to LEU or have shut down, and hundreds of kilograms of HEU have been removed from potentially vulnerable sites. Where information is available, this additional progress after the end of fiscal year 2006 is also discussed in the text.

It is important to understand from the outset what the percentages used in this report do and do not mean. As described in detail below, by the end of FY 2006, comprehensive security upgrades had been completed with U.S. assistance for 63% of the 215 buildings in the former Soviet Union where HEU or separated plutonium are located and the U.S. Department of Energy (DOE) has managed to reach cooperation agreements—representing perhaps 55% of the total number of buildings where these materials reside.[5] This does *not* necessarily mean that 45% of these buildings remain insecure—because at some sites where U.S.-sponsored upgrades have not been completed, Russia (or whatever state the facility is located in) may have undertaken substantial upgrades with its own resources. Nor does this figure mean that 55% of the buildings are definitely secure. At some sites or buildings where upgrades have been completed, security equipment may be broken or unused, the guard force may be inadequate, and a strong security culture may be lacking. The progress of these U.S.-funded upgrades is the best available numerical indicator of how nuclear security in the former Soviet Union is improving—but it is far from the whole story.

Such measures to track progress are essential for any major program. But in many cases, progress toward the most critical goals is difficult to measure, and metrics focusing on what *is* easily measurable can present a misleading picture. As Einstein is reported to have said, "not everything that counts can be counted, and not everything that can be counted, counts."

As programs to install upgraded security and accounting equipment in Russia near their end-2008 target date for completion, the most critical remaining policy issues are the intangible, difficult-to-measure ones -- particularly ensuring that effective security will be sustained for the long haul, and that the people who are essential to a strong security system give security the priority it requires, an issue that has come to be known as "security culture." At the same time, it is important to understand what programs to improve nuclear security can and cannot accomplish. Finally, since the danger of nuclear theft is not a Russian problem but a global problem, it is critical to understand what parts of a comprehensive nuclear security agenda are and are not underway in different countries around the world. This chapter, then, will outline some of these less measurable issues before detailing how far these nuclear security programs

[5] The U.S. federal fiscal year runs from 1 October to 30 September of the year named, so FY 2006 is the fiscal year that ended on 30 September 2006. At least the first stage of upgrades, known as "rapid upgrades," had been completed for an additional 18% of these buildings, for a total of 81% of the buildings where cooperation is underway (and perhaps 70% of the total number of buildings). These estimates and their sources are discussed in detail later in this chapter.

have progressed in meeting measurable benchmarks.[6]

Sustainability and Security Culture

Sustainability and security culture are both essential to effective, lasting nuclear security. The discussion below focuses on Russia, for that is where most U.S.-funded cooperation to improve nuclear security has focused and therefore where these issues have been confronted in the most depth—but both sustainability and security culture are nuclear security problems that must be addressed around the world, including in the United States.[7]

[6] Previous reports have presented measures of progress related to securing nuclear stockpiles; interdicting nuclear smuggling; stabilizing employment for nuclear personnel; monitoring nuclear stockpiles; ending production of more nuclear weapons and weapons-usable nuclear materials; and reducing excess stockpiles. In this year's report, I focus only on measures of progress on securing nuclear stockpiles, which provide the most immediate and direct impact in reducing the risk of nuclear theft and terrorism. In some of the other categories there will be little detectable progress until major facilities are completed (as is true of ending production and disposition of excess plutonium); in others, there is little progress because the U.S. government is no longer pursuing these objectives (as is the case for many of the items discussed relating to monitoring nuclear stockpiles); in still others, the measures tracked in previous reports covered only a portion of the problem and may have presented a misleading picture (particularly a problem in the cases of interdicting nuclear smuggling and stabilizing employment for nuclear personnel). Analyses of these other issues are available in the web section at http://www.nti.org/securingthebomb.

[7] For a very pointed official account of poor security culture at the U.S. Department of Energy, see President's Foreign Intelligence Advisory Board, *Science at Its Best, Security at Its Worst: A Report on Security Problems at the U.S. Department of Energy* (Washington D.C.: PFIAB, 1999; available at http://www.fas.org/sgp/library/pfiab/ as of 09 July 2007). While that report is eight years old and progress has been made in many areas, some of the underlying attitudes remain.

Sustainability

The goal of permanently reducing the danger of nuclear terrorism will not be achieved if the equipment now being installed is broken and unused five years after U.S. assistance comes to an end. Convincing partner countries to put in place the resources, incentives, and organizations that will ensure that effective nuclear security and accounting systems are maintained is critical to the success of these efforts. But sustainability is not an easy objective to achieve, or to measure.

In Russia, DOE and the U.S. Department of Defense (DOD) have been working intensely with their Russian counterparts on sustainability, and there is no doubt that considerable progress has been made. The United States and Russia have agreed on the objective of completing upgrades at both warhead sites and weapons-usable nuclear material sites in Russia by the end of 2008, and DOE, under Congressional direction, plans a several-year transition period after that, ending with Russian nuclear security and accounting systems sustained solely with Russian resources by the beginning of 2013.[8]

At many sites, upgrades are already completed, and the work that is ongoing focuses on sustainability. DOE has laid out what it believes are the seven overarching elements of a sustainable security and accounting system, and has been working closely with Rosatom (the succes-

[8] See, for example, discussion in U.S. Congress, General Accounting Office, *Nuclear Nonproliferation: Progress Made in Improving Security at Russian Nuclear Sites, but the Long-Term Sustainability of U.S.-Funded Security Upgrades Is Uncertain*, GAO-07-404 (Washington, D.C.: GAO, 2007; available at http://www.gao.gov/new.items/d07404.pdf as of 21 May 2007); U.S. Department of Energy, *2006 Strategic Plan: Office of International Material Protection and Cooperation, National Nuclear Security Administration* (Washington, D.C.: DOE, 2006).

sor agency to Russia's Ministry of Atomic Energy) and with other sites and agencies to ensure that these elements are put in place.[9] These seven elements, however, focus primarily on putting in place the *capability* to sustain good security (such as a maintenance infrastructure and appropriately trained personnel), rather than on *commitment* to provide the resources and attention required. Convincing foreign countries (and the management of sites in those countries) to assign a higher priority to security will be essential to long-term success, but remains a difficult challenge—and too few of the U.S. government's efforts are yet focused on that challenge.

In early 2007, DOE and Rosatom reached agreement on a sustainability plan—a very important milestone. DOE and Rosatom experts have been working through the specific steps the two sides agree need to be taken to achieve a sustainable system, and which side will pay for each of those needed actions—with more and more of the tasks to be paid for by Russia as the 2013 date draws nearer. The new agreement will provide a much-needed framework for putting the necessary capabilities in place (and the headquarters approval needed for site-level officials to move forward in these cooperative efforts).

The agreement reached to date is with Rosatom and covers only Rosatom facilities. DOE and DOD are working on sustainability with the Russian Ministry of Defense and sites controlled by other institutions as well, and have made progress in some important areas, such as training of personnel and the establishment of technical centers for nuclear security training and equipment maintenance. But they have not yet achieved the level of progress represented by the DOE-Rosatom agreement. At warhead sites in particular, problems with getting access to sites after upgrades have been completed may complicate DOE and DOD's ability to provide assistance targeted on sustainability.[10] Even at Rosatom sites, at least two critical elements of a sustainable nuclear security system remain to be put in place—effective rules and adequate resources.

Effective nuclear security rules. Most nuclear security managers will only invest in expensive nuclear security measures if the government tells them they have to. Hence, effective nuclear security and accounting rules, effectively enforced, are absolutely critical to achieving and maintaining an effective nuclear security system.[11] As discussed in Chapter 1, Russia's nuclear security and accounting regulations are still weak, and its nuclear

[9] For a useful overview of DOE's seven elements of sustainability, with DOE's "indicators" of whether or not each element is in place at a site, see U.S. Congress, *Nuclear Nonproliferation: Progress Made in Improving Security at Russian Nuclear Sites, but the Long-Term Sustainability of U.S.-Funded Security Upgrades Is Uncertain*, p. 24. For a good overview of the sustainability issue in general, with recommendations, see Committee on Indigenization of Programs to Prevent Leakage of Plutonium and Highly Enriched Uranium from Russian Facilities, Office for Central Europe and Eurasia, National Research Council, *Strengthening Long-Term Nuclear Security: Protecting Weapon-Usable Material in Russia* (Washington, D.C.: National Academy Press, 2005; available at http://fermat.nap.edu/catalog/11377.html as of 09 July 2007). That report refers to sustainability as "indigenization," to avoid the implication that what is involved is simply sustaining systems imposed from outside.

[10] U.S. Congress, *Nuclear Nonproliferation: Progress Made in Improving Security at Russian Nuclear Sites, but the Long-Term Sustainability of U.S.-Funded Security Upgrades Is Uncertain*.

[11] Effective regulation is a particularly critical element of the broader problem of creating effective incentives for good security, to counteract the strong incentives to cut corners on security. See Matthew Bunn, "Incentives for Nuclear Security," in *Proceedings of the 46th Annual Meeting of the Institute for Nuclear Materials Management, Phoenix, Ariz., 10-14 July 2005* (Northbrook, Ill.: INMM, 2005).

regulators have far less power than the agencies they are supposed to regulate.

Russia's nuclear security and accounting regulators also have very limited resources, making it difficult to carry out all the inspections that may be needed, and to offer competitive salaries to recruit the best personnel as inspectors. In particular, the separate Ministry of Defense (MOD) body that regulates safety and security for MOD's nuclear activities and those parts of Rosatom that relate to manufacture of nuclear weapons and components have even fewer resources than does the nuclear part of the broader regulatory agency, Rostekhnadzor. And since virtually all of MOD's nuclear activities relate to countable items (such as nuclear warheads or fuel assemblies), whether this body has the appropriate expertise to regulate accounting and control of plutonium and HEU processed in bulk forms at the Rosatom facilities making nuclear weapons components remains an open question. There are also persistent reports that inspectors who find major violations at sites that have no money to fix them allow sites to delay correcting the problems until money becomes available.[12] Moreover, while all other countries with substantial nuclear programs have independent nuclear regulatory agencies, Russia's nuclear regulatory body has become one small part of Rostekhnadzor, a much larger regulatory agency responsible for overseeing safety and technical issues throughout the Russian economy. This makes it more difficult for nuclear safety and security issues raised by regulators to percolate to the highest levels of the government.

DOE experts, working with Russian experts, have laid out a structure of hundreds of key elements they believe an appropriate nuclear security and accounting system should have, and DOE is working closely with Russian regulators to get regulations drafted and issued that include those fundamental elements.[13] Building a structure of effective rules, effectively enforced, must be a top priority for the program—not just in Russia but anywhere that the United States and other donors are sponsoring security upgrades—for without them, sustainable nuclear security is unlikely to be achieved. But this process will take years, and whether Russia will give its regulators the resources, authority, and expert personnel they need to ensure that all of Russia's stockpiles are effectively secured and accounted for remains to be seen.

Adequate nuclear security resources. As yet, there are few signs of the needed seachange in the level of resources Russia assigns to nuclear security. While Russia now has substantial resources (fueled by both revenues from high oil prices and broader economic growth), Russian leaders have not made nuclear security a budget priority, and individual nuclear sites—many of which still have few sources of income—have to come up with the money to fund most nuclear security and accounting measures. Three out of four civilian nuclear facilities visited by investigators from the U.S. Government Accountability Office expressed concern that they might not be able to afford to maintain the upgraded security systems at their sites when U.S. assistance phased

[12] Interviews with DOE officials, June 2005 and June 2007.

[13] See, for example, Greg E. Davis et al., "Creating a Comprehensive, Efficient and Sustainable Nuclear Regulatory Structure: A Process Report from the U.S. Department of Energy's Material Protection, Control and Accounting Program," in *Proceedings of the 47th Annual Meeting of the Institute for Nuclear Materials Management, Nashville, Tenn., 16-20 July 2006* (Northbrook, Ill.: INMM, 2006).. Also interviews with DOE officials, July 2006 and June 2007.

out.[14] As noted in the last chapter, a leading Russian expert estimated in 2005 that physical protection at Russian nuclear sites receives only 30% of the funding required.[15] Russian President Putin has not yet issued clear instruction that security for nuclear sites should receive priority in budget allocations, or set aside specific lines in the relevant agencies' budgets exclusively for this purpose. The amount of money required just to operate, maintain, replace, and upgrade the equipment now being installed is likely to be substantial—probably over $100 million per year. When all the other costs of an effective nuclear security and accounting system are added in, including the salaries and other costs for all the guards, material accounting experts, regulators, and the like, Russia's costs are surely going to be in the hundreds of millions of dollars per year. (DOE now spends well over $1 billion per year on security in its own complex.) Russia can easily afford to pay such costs, but will do so only if the Russian government assigns a higher priority to the problem of nuclear security than it has done so far.

Security Culture

Building strong security cultures—the habit, among all security-relevant personnel, of taking security seriously and taking the actions needed to ensure high security—is also critical to the success of nuclear security improvement programs. If security doors are left propped open for convenience, guards patrol without ammunition in their guns to avoid accidental firing incidents, and security personnel turn off alarm systems out of annoyance with their false alarms,[16] good security is not likely to be achieved.[17] As Gen. Eugene Habiger, former DOE "security czar" and former commander of

[14] U.S. Congress, *Nuclear Nonproliferation: Progress Made in Improving Security at Russian Nuclear Sites, but the Long-Term Sustainability of U.S.-Funded Security Upgrades Is Uncertain*, p. 27.

[15] Nikolai N. Shemigon, director-general, Eleron (Rosatom's physical protection firm), remarks to "Third Russian International Conference on Nuclear Material Protection, Control, and Accounting," 16-20 May 2005, Obninsk, Russia.

[16] All of these are behaviors that have been observed at sites in Russia where U.S.-funded Material Protection, Control, and Accounting (MPC&A) cooperation is taking place. All of these are also behaviors that have been observed at U.S. sites in the past. For a remarkable account of weak security culture, ineffectiveness, and corruption among nuclear guards in Russia, written by the security chief of one of Russia's largest plutonium and HEU facilities, see Igor Goloskokov, "Refomirovanie Voisk MVD Po Okhrane Yadernikh Obektov Rossii (Reforming MVD Troops to Guard Russian Nuclear Facilities)," trans. Foreign Broadcast Information Service, *Yaderny Kontrol* 9, no. 4 (Winter 2003; available at http://www.pircenter.org/data/publications/yk4-2003.pdf as of 25 July 2007). Goloskovov's article includes a description of guards routinely patrolling with no ammunition. For a photograph of a propped-open security door (installed with U.S. assistance), see U.S. Congress, General Accounting Office, *Nuclear Nonproliferation: Security of Russia's Nuclear Material Improving; Further Enhancements Needed*, GAO-01-312 (Washington, D.C.: GAO, 2001; available at http://www.gao.gov/new.items/d01312.pdf as of 2 January 2007), p. 14. For an excellent broader account of the issue, see Igor Khripunov and James Holmes, eds., *Nuclear Security Culture: The Case of Russia* (Athens, Georgia: Center for International Trade and Security, The University of Georgia, 2004; available at http://www.uga.edu/cits/documents/pdf/Security%20Culture%20Report%2020041118.pdf as of 12 July 2007).

[17] Approaches that provide "inherent security" with limited reliance on human intervention—putting nuclear material in a steel cage that would take a long time to cut through, piling huge concrete blocks in front of the door, and the like—are a partial exception. Such technologies, however, are typically only applicable to items that are in long-term storage, not in regular use. Moreover, staff with little regard for security can undermine even these approaches' effectiveness—by not replacing the concrete blocks after the room has been accessed, for example, to make it more convenient to get in again the next day or the next week. And even these approaches offer only delay, ultimately relying on human intervention to stop adversaries from getting at the weapons or materials being protected.

U.S. strategic forces, put it: "good security is 20% equipment and 80% culture."[18]

DOE has launched an impressive pilot program focused on improving security culture at selected nuclear sites in Russia, and has put together an enthusiastic and creative team of Russian experts who are pushing the effort forward. The effort includes "security culture coordinators" at each of the selected sites, whose job is to promote security awareness at those locations, along with a variety of briefings, videos, training courses, and other strategies to promote a strong security culture. Since the Bratislava nuclear security summit statement emphasized security culture in 2005, there has been an intensified high-level dialogue with Russian officials on improving security culture, and the culture program has expanded to additional sites (including Seversk, one of Russia's largest plutonium and HEU sites).

But whether these efforts will succeed on the scale required remains an open question. Unfortunately, changing any deeply ingrained aspect of organizational culture, including security culture, is very difficult to do.[19] In general, these changes do not occur unless the top leaders of the organization dedicate themselves to making them happen and devote a substantial and sustained effort to the task[20]—which means that the first job is to convince senior nuclear managers of the importance of achieving strong security cultures in their organizations. As the string of security incidents at the Los Alamos National Laboratory in recent years makes clear, the United States still faces major challenges with security culture even at facilities where the U.S. government sets all the rules and provides all the funding;[21] in early 2007, the head of the National Nuclear Security Administration was fired for his inability to fix this security culture problem at Los Alamos.[22] Trying to improve security culture in other countries, whose national cultures U.S. officials may not understand well and where U.S. programs have limited influence, poses a far greater challenge—but a crucial one. Assessing how well programs are doing in meeting this challenge is also extraordinarily difficult, requiring the development and use of a variety of partial and indirect indicators of progress.

[18] Interview by author, April 2003.

[19] A classic text on organizational culture (though one much critiqued in some circles) is Edgar H. Schein, *Organizational Culture and Leadership*, Third ed. (San Francisco, CA: Jossey-Bass, 2004). See also John P. Kotter, *Leading Change*, First ed. (Boston, MA: Harvard Business School Press, 1996).

[20] See, for example, discussion in Kotter, *Leading Change*.

[21] For statements attributing the ongoing problem at Los Alamos to the security culture at the laboratory, see, for example, House Committee on Energy and Commerce, Energy and Air Quality Subcommittee, *A Hearing to Review Proposals to Consolidate the Offices of Counter Intelligence at NNSA and DOE*, 13 July 2004 (available at http://energycommerce.house.gov/reparchives/108/Hearings/07132004hearing1346/hearing.htm as of 10 July 2007). For a remarkable official excoriation of the security culture at the Department of Energy and its predecessors, stretching back over decades, see President's Foreign Intelligence Advisory Board, *Science at Its Best, Security at Its Worst*. This report lays blame for much of the security problem at DOE on cultural attitudes toward security, which it describes in stark terms: "Never have the members of the Special Investigative Panel witnessed a bureaucratic culture so thoroughly saturated with cynicism and disregard for authority…. DOE and the weapons laboratories have a deeply rooted culture of low regard for and, at times, hostility to security issues… The predominant attitude toward security and counterintelligence among many DOE and lab managers has ranged from half–hearted, grudging accommodation to smug disregard."

[22] Steven Mufson, "After Breaches, Head of U.S. Nuclear Program Is Ousted," *Washington Post*, 5 January 2007.

Seeing the Threat—the Crucial Ingredient

If political leaders and nuclear managers believe that nuclear theft and terrorism are real and urgent threats—to their own countries, not just to the United States—they are very likely to take the actions needed to sustain effective nuclear security programs and build strong security cultures. If they do not believe nuclear terrorism is an important threat, neither sustainability nor strong security cultures are likely to be achieved.

Unfortunately, many nuclear officials around the world simply do not believe that nuclear terrorism is a plausible threat. Alexander Kotelnikov, then the Deputy Minister of Atomic Energy in charge of securing most of Russia's nuclear stockpiles, summed up this view succinctly, saying that it would be "absolutely impossible" for terrorists to make a nuclear bomb even if they got the nuclear material needed to do so.[23] If nuclear security improvement efforts are to succeed, much more needs to be done to convince key officials and nuclear managers around the world of the reality of the nuclear terrorism threat.

What Nuclear Security Programs Can and Cannot Do

Beefing up security at the world's most vulnerable nuclear sites, or removing the nuclear weapons or weapons-usable nuclear material from them entirely, has the potential to dramatically reduce the risk that terrorists might be able to get their hands on nuclear weapons or their essential ingredients. But it cannot eliminate this risk, for several reasons.

First, some nuclear materials may already have been stolen, and may already be outside whatever improved fences and security barriers may now be installed. The CIA assesses that undetected thefts of nuclear material have probably occurred—but no one knows how much might already have been stolen.[24] (Given that there is no convincing evidence that al Qaeda succeeded in acquiring stolen nuclear material despite attempting to do so for many years before the 9/11 attacks, however, there is reason to hope that already-stolen material represents only a small portion of the threat of nuclear terrorism.)

Second, some threats are bigger than plausible security systems will be able to handle. If the government of a state where nuclear stockpiles exist collapses; if a site is attacked by a rogue military unit or other group of scores or hundreds of well-armed outsiders; or if senior managers of the site decide to sell off nuclear material, improved fences and intrusion detectors at the site simply will not solve the problem. In Pakistan, for example, many of the scenarios often described—such as state failure, Taliban-linked jihadists seizing power, hundreds of jihadists attacking a nuclear site all at once, or senior generals deciding to provide nuclear assistance to jihadis—will not be solved by installing better nuclear security systems; however large or small these risks may be, other policy tools will be needed to address them. Hence, improved security and accounting measures can only reduce, never eliminate, the risk that a particular cache of nuclear weapons or materials will be stolen; only removing

[23] Aleksandr Khinshteyn, "Secret Materials," trans. BBC Monitoring Service, "Russian Central TV," 29 November 2002.

[24] U.S. National Intelligence Council, *Annual Report to Congress on the Safety and Security of Russian Nuclear Facilities and Military Forces* (Washington, D.C.: Central Intelligence Agency, 2004; available at http://www.dni.gov/nic/special_russiannuke04.html as of 10 July 2007).

the material from a site entirely can eliminate the threat of theft from that site.

Third, reducing the danger of nuclear theft will not address the possibility of a state providing nuclear weapons or materials to terrorists. As discussed in Chapter 1, however, the danger that a state such as North Korea or Iran would intentionally provide nuclear material to terrorists is probably a far smaller part of the risk of nuclear terrorism than the danger of nuclear theft.

Finally, a U.S.-funded cooperative program can have a big influence on some of the key elements of an effective nuclear security system, but not on other equally critical elements. The United States and other donors can work with countries and provide assistance to ensure that modern security and accounting equipment is installed and appropriate training provided. But assigning a sufficient number of well-trained, well-equipped, and well-motivated guards to protect these sites is up to each country where these materials exist (though donors can help provide equipment and training). The United States and other donors can help countries write more effective nuclear security and accounting regulations and help train inspectors and regulators; but it is up to each of these countries to give their regulators the power and resources needed to regulate nuclear security and accounting effectively. The United States and other donors can share approaches and "best practices" in checking employees backgrounds and other measures to ensure that nuclear personnel are trustworthy; but it is up to each of these countries to investigate and monitor the employees at their nuclear facilities effectively—and to fight corruption than can create major security weaknesses. The United States and other donors can provide the equipment and training needed to implement nuclear security and accounting properly—but ensuring that the staff do not cut corners in day-to-day implementation is inevitably up to each country where these stockpiles exist. For these reasons, DOE's frequent use of the term "secured" to describe a site where equipment upgrades have been completed is misleading—for there may be much more to do before the nuclear stockpiles at that site can be considered fully secure.

Nuclear Security Steps Underway—and Not Underway

Fundamentally, what needs to be done is to:

- Consolidate nuclear weapons and the materials to the smallest practicable number of secure locations worldwide; and

- ensure that all the locations where such stocks will remain—and the transports between them—are effectively and sustainably secured against plausible terrorist and criminal threats.

These steps need to be taken not just in the former Soviet Union but everywhere where these stockpiles exist—in nuclear weapon states and non-nuclear-weapon states, in developed countries and developing countries.

Before turning to measures of how much of this broad agenda has been accomplished, it is worth briefly discussing which parts of such an effort are well underway; which are just beginning or not yet agreed; and which are not yet even on the agenda.

Consolidation

The United States. U.S. nuclear warheads used to be deployed in many countries, at a large number of sites. Except for

a few hundred air-delivered weapons remaining in Europe, U.S. nuclear weapons have been pulled back to the United States, and consolidated in a smaller number of locations.[25] Part of this was the result of the 1991-1992 Presidential Nuclear Initiatives.[26] For roughly the past decade, however, U.S. nuclear weapons deployments have not been consolidated significantly.

DOE is currently engaged in a major effort to consolidate nuclear materials in its complex to a smaller number of buildings and sites—in part to reduce the high costs of meeting DOE's post-9/11 security requirements for plutonium and HEU. The Rocky Flats site has been entirely closed, with all nuclear material removed; all nuclear material has been removed from the vulnerable TA-18 site at Los Alamos (with the critical assemblies that were still needed moved to the highly secure Device Assembly Facility (DAF) at the Nevada Test Site); and all weapons-usable nuclear material is being removed from all of Sandia National Laboratory. Under current plans, removing all potential nuclear bomb material from Hanford, Livermore, and Los Alamos will take somewhat longer. These consolidations are saving hundreds of millions of dollars a year in security costs. Critics argue that further and faster consolidation should be pursued, and would save even more money.[27]

DOE has also recently resumed funding conversion of U.S. HEU-fueled research reactors to low-enriched uranium (LEU) after a break of many years; the reactors at the University of Florida and at Texas A&M were converted in 2006, and two more are expected to be converted in 2007.[28] At the same time, however, disposition of excess plutonium will add major plutonium-handling facilities at the Savannah River Site, along with at least two commercial power reactors that will have fabricated MOX fuel containing unirradiated plutonium on-site. In addition, the Global Nuclear Energy Partnership (GNEP), if it proceeds, will lead to construction of facilities that will separate plutonium and other radioactive materials from spent fuel, fabricate these materials into fuel, and use these fuels in power reactors; DOE argues that the approaches it will pursue will be proliferation resistant and will not involve separated plutonium, but critics have pointed out that the materials to be separated, processed, and recycled will be far easier to steal and recover plutonium from than plutonium in spent fuel.[29]

[25] Compare, for example, unclassified estimates concerning the locations of U.S. nuclear weapons in William M. Arkin, Robert S. Norris, and Joshua Handler, *Taking Stock: Worldwide Nuclear Deployments 1998* (Washington, D.C.: Natural Resources Defense Council, 1998; available at http://www.nrdc.org/nuclear/tkstock/download.asp as of 07 August 2007). to the earlier description of the global sprawl of the U.S. weapons stockpile in William M. Arkin and Richard W. Fieldhouse, *Nuclear Battlefields: Global Links in the Arms Race* (Cambridge, Mass.: Ballinger, 1985).

[26] For a summary of these initiatives, see, for example, Joshua Handler, "The September 1991 PNIs and the Elimination, Storing, and Security Aspects of TNWs," paper presented at Time to Control Tactical Nuclear Weapons: Seminar Hosted by the United Nations Institute for Disarmament Research, the Center for Nonproliferation Studies, and the Peace Research Institute Frankfurt, New York, 24 September 2001 (available at http://www.princeton.edu/~globsec/publications/pdf/untalk.pdf as of 2 January 2007).

[27] Project on Government Oversight, *U.S. Nuclear Weapons Complex: Homeland Security Opportunities* (Washington, D.C.: POGO, 2005; available at http://pogo.org/p/homeland/ho-050301-consolidation.html as of 09 July 2007).

[28] See U.S. Department of Energy, National Nuclear Security Administration, *Strategic Plan: Reducing Nuclear and Radiological Threats Worldwide* (Washington, D.C.: DOE, 2007).

[29] See, for example, Richard L. Garwin, "Plutonium Recycle in the U.S. Nuclear Power System?" paper presented at American Association for the Advancement of Science Annual Meeting, San Francisco,

Russia. Russia has also consolidated its nuclear warhead stockpiles to a smaller number of sites, with the pullback of nuclear warheads from Eastern Europe and the non-Russian states of the former Soviet Union, along with the closure of some sites in Russia. But there are still scores of nuclear warhead storage sites in Russia, the largest number of such sites in the world, and a huge infrastructure that will be expensive and difficult to secure. No initiative to consolidate Russia's warheads to a smaller number of sites is currently underway.[30] Indeed, U.S. cooperative threat reduction assistance is likely having the opposite effect, as DOD's agreement with Russia on warhead site security upgrades requires that Russia not close any warhead sites that receive upgrade assistance for at least three years.[31]

Similarly, Russia has the world's largest number of buildings with weapons-usable nuclear material, estimated at over 200 buildings at dozens of sites. During the course of cooperative security upgrades, the nuclear material at a number of sites has been consolidated into fewer buildings; the Russian Navy, in particular, has greatly reduced the number of buildings and sites where HEU fuel is stored. DOE's International Nuclear Material Protection and Cooperation program (better known by its former name, as the Material Protection, Control, and Accounting, or MPC&A, program) has a Material Consolidation and Conversion (MCC) initiative, which has been moderately successful in blending down HEU removed from potentially vulnerable civilian sites in Russia (with 8.4 tons of HEU blended by the end of FY 2006).[32] MCC has been less successful, however, in cleaning out all the weapons-usable material from particular sites, though all HEU was removed from the Krylov Shipbuilding Institute in 2006. Russia has so far refused to engage seriously on converting its HEU-fueled reactors to LEU (insisting on limiting that activity to "third countries" in the Bratislava nuclear security summit statement), or on shutting down the large numbers of hardly-utilized research reactors in Russia. As Russia has the world's largest number of HEU-fueled research reactors, this is a significant issue.

In the future, Russia plans to use plutonium fuel—or, like the United States, fuel made from plutonium mixed with other materials in the hope that this would make the fuel more difficult to steal and recover bomb material from—in an increasing number of reactors. The first of these, under the weapons plutonium disposition program, are likely to be the existing BN-600 fast neutron reactor (which currently operates with HEU in the range of 22-27% enrichment) and the larger BN-800 fast neutron reactor now under construction.

15-19 February 2007 (available at http://www.fas.org/rlg/021507PlutoniumRecycle3L.pdf as of 27 July 2007). For a more detailed technical analysis, see Jungmin Kang and Frank Von Hippel, "Limited Proliferation-Resistance Benefits from Recycling Unseparated Transuranics and Lanthanides from Light-Water Reactor Spent Fuel," *Science and Global Security* 13, no. 3 (2005).

[30] For discussions of the importance of consolidation of these sites, see Gunnar Arbman and Charles Thornton, *Russia's Tactical Nuclear Weapons: Part II: Technical Issues and Policy Recommendations*, vol. FOI-R—1588—SE (Stockholm: Swedish Defense Research Agency, 2005; available at http://www.foi.se/upload/pdf/FOI-RussiasTacticalNuclearWeapons.pdf as of 09 July 2007); Harold P. Smith, Jr., "Consolidating Threat Reduction," *Arms Control Today* 33, no. 9 (November 2003; available at http://www.armscontrol.org/act/2003_11/Smith.asp as of 09 July 2007), p. 19.

[31] U.S. Department of Defense, *Cooperative Threat Reduction Annual Report to Congress: Fiscal Year 2006* (Washington, D.C.: U.S. Department of Defense, 2005), p. 38..

[32] U.S. Department of Energy, *FY 2008 NNSA Budget Request*, p. 474.

Other States With Nuclear Weapons. Other states with nuclear weapons have far smaller stockpiles of nuclear weapons in many fewer locations. France and Britain have both reduced their nuclear weapon stockpiles, and the number of locations where these stockpiles exist, in recent years. Neither appears to plan further consolidation. The other states with nuclear weapons do not appear to plan further consolidation of their nuclear weapon stockpiles.

With respect to civilian materials, France, Britain, and China have been participating in efforts to convert HEU-fueled research reactors to LEU (though one new research reactor may be started with HEU in France), and India may do so in the future. Pakistan's single research reactor has been converted to LEU, though some irradiated HEU fuel remains on-site. Israel also maintains an HEU-fueled research reactor, in addition to its nuclear weapons stockpile.

France uses reactor-grade plutonium fuel in a large number of its own power reactors, and fabricates such fuel for other countries as well. Britain also has a commercial plutonium fuel fabrication plant, but does not use this fuel in its own reactors. (Reactor-grade plutonium, like weapon-grade plutonium, is usable in nuclear explosives.)[33] India already reprocesses some civilian plutonium and is building a major plutonium breeder reactor; China plans to begin reprocessing civilian plutonium in the near future. There are no U.S. programs targeted on reducing the number of sites in these countries using separated plutonium. Indeed, the recent U.S.-India nuclear cooperation agreement gives India prior approval for reprocessing, requiring India to build a new reprocessing plant to take advantage of that approval.[34]

Non-Nuclear Weapon States. Most of the weapons-usable nuclear material in non-nuclear-weapon states is in developed states, such as Germany, Canada, and Japan. The vast majority of the non-nuclear-weapon states with HEU-fueled research reactors are participating in efforts to convert these reactors to LEU fuel and remove the HEU from them; as a result, the number of sites with HEU in these states is declining. Several non-nuclear weapon states use plutonium-uranium mixed oxide (MOX) fuel in their power reactors; while some (like Switzerland and Belgium) are moving toward ending this practice, others (such as Japan) are seeking to begin. This results in a significant number of additional locations with weapons-usable nuclear material (and of weapons-usable material transports) that must be secured. There are no U.S. programs targeted on reducing the number of sites in these countries using separated plutonium.

Security Upgrades and Security Standards

The United States. The United States may have the most stringent nuclear security rules in the world and almost certainly spends more on securing its nuclear

[33] For the most detailed official unclassified statement on this subject, see U.S. Department of Energy, Office of Arms Control and Nonproliferation, *Nonproliferation and Arms Control Assessment of Weapons-Usable Fissile Material Storage and Excess Plutonium Disposition Alternatives*, DOE/NN-0007 (Washington, D.C.: DOE, 1997; available at http://www.osti.gov/bridge/servlets/purl/425259-CXr7Qn/webviewable/425259.pdf as of 2 January 2007), pp. 37-39.

[34] See Article VI of *Agreement for Cooperation Between the Government of the United States of America and the Government of India Concerning Peaceful Uses of Nuclear Energy (123 Agreement)* (Washington, D.C.: U.S. Department of State, 2007, at http://www.armscontrol.org/projects/india/20070803_123.asp available as of 10 September 2007).

stockpiles than any other country. Annual safeguards and security spending at DOE alone is now in the range of $1.5 billion per year.[35] The private sector and the Department of Defense spend hundreds of millions more each year. All facilities with nuclear weapons or weapons-usable nuclear material are required to be able to protect against a specified design basis threat (DBT); both armed guards and modern safeguards and security technologies are used to protect these sites (and to protect transports). Regular performance tests probing facilities' ability to fend off mock attackers are required. While details are classified, the DBT now in place for nuclear weapons and weapons-usable nuclear material at DOE is reported to be comparable in magnitude to the 19 attackers in four independent, well-coordinated groups that struck on 9/11.[36] Nevertheless, even in the United States there have been repeated controversies over whether nuclear facilities are adequately secured and repeated cases of security tests revealing serious vulnerabilities in physical protection and accounting systems for nuclear material in the U.S. nuclear complex.[37]

The nuclear security improvements in the United States since 9/11 have been notably uneven. The Nuclear Regulatory Commission (NRC) has increased security requirements for the two major HEU-processing facilities it regulates, but to a standard far less than DOE sites with nearly identical materials are being required to meet.[38] HEU at NRC-regulated research reactors is exempt from most of the security requirements that the same material would require if it was located anywhere other than a research reactor. HEU emitting more than 100 rad/hour at one meter is exempt from nearly all of the NRC's security requirements—even though it is now widely understood that this level of radiation provides essentially no protection against potentially suicidal thieves. Hence, U.S. HEU-fueled research reactors regulated by the NRC continue to have only the most modest security measures in place.[39]

Russia and the former Soviet Union. As discussed in detail below, nuclear security and accounting equipment upgrades

[35] U.S. Department of Energy, *FY 2007 Congressional Budget Request: Other Defense Activities*, vol. 2, DOE/CF-003 (Washington, D.C.: DOE, 2006; available at http://www.cfo.doe.gov/budget/07budget/Content/Volumes/Vol_2_ODA.pdf as of 10 July 2007), p. 161.

[36] For a useful discussion of the several steps in the evolution of DOE's DBT since 9/11, see Project on Government Oversight, *U.S. Nuclear Weapons Complex: Y-12 and Oak Ridge National Laboratory at High Risk* (Washington, D.C.: POGO, 2006; available at http://pogo.org/p/homeland/ho-061001-Y12.html as of 09 July 2007).

[37] For a blistering critique of security in the U.S. nuclear weapons complex, published shortly after the 9/11 attacks, see Project on Government Oversight, *U.S. Nuclear Weapons Complex: Security at Risk* (Washington, D.C.: POGO, 2001; available at http://www.pogo.org/p/environment/eo-011003-nuclear.html as of 07 August 2007). For a recent summary of progress made in improving security since then and problems still remaining, including both official views and those of critics, see Committee on Energy and Commerce, Subcommittee on Oversight and Investigations, *A Review of Security Initiatives at DOE Nuclear Facilities*, U.S. Congress, House of Representatives, 109th Congress, 1st Session, 18 March 2005 (available at http://energycommerce.house.gov/reparchives/108/Hearings/03182005hearing1457/hearing.htm as of 10 July 2007). For a brutal earlier official review (including a long history of past negative assessments), see President's Foreign Intelligence Advisory Board, *Science at Its Best, Security at Its Worst*.

[38] The two sites are Nuclear Fuel Services, in Erwin, Tennessee and the Nuclear Productions Division of BWXT Technologies, in Lynchburg, Virginia. See, for example, the brief mention of this point in Project on Government Oversight, *U.S. Nuclear Weapons Complex: Homeland Security Opportunities*.

[39] To be fair, these reactors typically have only very small amounts of fresh HEU fuel on-site; the bulk of the HEU at these sites is either in the fuel in the reactor core, or in the irradiated fuel in a pool. In many cases, however, irradiated HEU fuel also poses a significant proliferation threat, as discussed in Chapter 1.

have been completed at a large number of warhead sites and nuclear material sites in Russia, and these efforts are racing to meet an end-of-2008 target for completing these upgrades (at least at the sites that have been agreed). There are, however, sites that are not covered by current cooperative programs. And, as discussed above, a wide range of issues that are crucial to effective nuclear security for the long haul still have to be addressed—sustainability, security culture, resource commitments, effective regulations, and more. Nuclear security upgrades have also been completed at all of the sites with weapons-usable nuclear materials in the former Soviet states outside of Russia. Here, too, however, the same key issues still need to be addressed.

Other Nuclear Weapon States. Pakistan has now acknowledged that it is cooperating with the United States to improve nuclear security and accounting measures,[40] but virtually no information concerning how much progress has been made is publicly available. Given the extreme sensitivity surrounding Pakistan's nuclear stockpiles, it is likely that this cooperation does *not* include actual visits by U.S. personnel to Pakistani warhead sites and other military nuclear sites, but rather training and exchanges of information concerning modern safeguards and security approaches, provision of equipment to be installed by Pakistani personnel, and the like. Given the relatively new state of this cooperation, it is likely that discussions with Pakistan on matters of sustainability, effective regulation, and security culture are at an even earlier stage than those with Russia.

The United States is also cooperating with China on nuclear material security and accounting. Security and accounting upgrades were implemented at one civilian site with weapons-usable nuclear material by the end of 2005, as a demonstration facility and one part of a larger effort to showcase nuclear security best practices and technologies. The bulk of the effort, however, is focused on discussions, training, and exchanges of information rather than on U.S. financing for upgrades at particular sites; the United States expects China to pay for actual upgrades at its sites itself. How much impact this effort has yet had on the actual security measures on the ground at China's nuclear sites remains unclear; as of October 2006, Chinese experts indicated that China had not yet put in place regulations requiring its facilities to be able to defend against any specified DBT, and that detailed vulnerability assessments had not been performed at the vast majority of Chinese sites.[41] This cooperation appears to be at too early a stage for issues such as sustainability, security culture, and effective regulation to have been effectively addressed, though discussions of these issues have recently begun or are planned.[42]

To date, India is still refusing cooperation with the United States on MPC&A, though it has hosted some IAEA-organized regional training sessions on physical protection. The United States has not attempted nuclear security cooperation with Israel (which, given its small stockpile and extensive experience with terrorism, probably has reasonably stringent nuclear security) or with North Korea. U.S. cooperation with Britain and France is in the form of discussions of key issues and exchanges of experience, rather than nuclear security assistance. As with

[40] Nirupama Subramanian, "Pakistan Accepted U.S. Help on N-Plants," *The Hindu*, 22 June 2006 (available at http://www.thehindu.com/2006/06/22/stories/2006062205201400.htm as of 09 July 2007).

[41] Interviews with Chinese experts, October 2006.

[42] Data provided by DOE, September 2007.

the United States, some critics have raised significant issues concerning nuclear security in both Britain and France.[43] Under U.S. law, the United States conducts occasional visits to confirm that U.S.-origin nuclear material in Britain, France, and other countries is protected in accordance with IAEA recommendations.

Non-Nuclear Weapon States. The United States does not finance nuclear security improvements in wealthy non-nuclear-weapon states such as Germany, Japan, and Canada, though it is not unusual for the United States to seek, through discussions, to convince such states to take steps to strengthen nuclear security. (Extensive U.S.-Japanese discussions, for example, helped encourage Japan to strengthen its physical protection rules, though the protections required in Japan are still modest.[44]) In the case of non-nuclear-weapon states in the developing world, the United States does provide assistance with security upgrades at HEU-fueled research reactors, which are typically the only sites with significant weapons-usable nuclear materials in these countries.

Global Nuclear Security Standards. Nuclear security is only as strong as its weakest link; there is therefore an urgent need to put in place stringent global standards for nuclear security. Today, how secure nuclear weapons and materials should be is largely left to the discretion of each of the states that own these materials; there are no specific and binding global nuclear security standards.

There has been significant progress in recent years in building a broader legal foundation for nuclear security around the world, with an amendment to the physical protection convention; a new nuclear terrorism convention; and UN Security Council Resolution 1540, which legally requires every state with nuclear weapons or materials to provide "appropriate effective" security and accounting for them.[45] Unfortunately, however, none of these measures include any specific nuclear security standards. For example, no one has yet sought to lay out what the essential elements of an "appropriate effective" nuclear security and accounting system are, and to hold states accountable for putting those measures in place.[46]

There are also IAEA recommendations on physical protection; although purely advisory, these are widely followed (and

[43] For a troubling analysis of security for plutonium transports in France, for example, see Ronald E. Timm, *Security Assessment Report for Plutonium Transport in France* (Paris: Greenpeace International, 2005; available at http://greenpeace.datapps.com/stop-plutonium/en/TimmReportV5.pdf as of 09 July 2007).

[44] Prior to the 9/11 attacks, Japan did not have armed guards at nuclear facilities, relying instead on armed response units some distance away. Since 9/11, lightly armed members of the national police force have been stationed at nuclear facilities, but they are not required by regulation and may be withdrawn at any time. A senior Japanese regulator estimates that the total cost to all licensees combined of meeting the new physical protection rules was in the range of $50 million. Interview with Japanese nuclear regulator, November 2006.

[45] For texts of these documents, see *Amendment to the Convention on the Physical Protection of Nuclear Material* (Vienna: International Atomic Energy Agency, 2005; available at http://www-pub.iaea.org/MTCD/Meetings/ccpnmdocs/cppnm_proposal.pdf as of 09 July 2007); *International Convention for the Suppression of Acts of Nuclear Terrorism* (New York: United Nations, 2005; available at http://www.un.int/usa/a-59-766.pdf as of 25 July 2007); United Nations, "1540 Committee" (New York: UN, 2005; available at http://disarmament2.un.org/Committee1540/meeting.html as of 09 July 2007).

[46] For recommendations for next steps along these lines, see Matthew Bunn, "UNSC 1540: Next Steps to Seize the Opportunity," paper presented at A New Role for the United Nations Security Council: Criminalizing WMD Proliferation--The Impact of U.N. Security Council Resolution 1540, Arlington, Va., 15 March 2005 (available at http://bcsia.ksg.harvard.edu/BCSIA_content/documents/UNSC1540.pdf as of 09 July 2007).

indeed, many states have agreements with nuclear suppliers that require them to follow these recommendations). While more specific than any of the legally binding agreements, these recommendations are still quite vague; they specify, for example, that sites with the most sensitive nuclear material should have a fence with intrusion detectors, but do not specify how strong the fence should be or how effective the detectors should be. They recommend that a site should have a 24-hour guard force, but do not require that the guards should be armed and do not specify what they should be able to defend against. The most recent revision of these recommendations was completed in 1999, long before the 9/11 attacks; international discussions of a new revision are just beginning. No effort to achieve stringent and binding global nuclear security standards is currently underway.

In short, while enormous progress has been made in installing modern security and accounting equipment in Russia and the former Soviet Union, in much of the rest of the world, efforts to consolidate and secure nuclear stockpiles are still only in their earliest stages, and many key elements of such an agenda—from consolidating nuclear warhead storage sites to constricting the spread of sites using separated plutonium for civilian fuel -- are not yet even on the agenda. The goal of ensuring that every stockpile of nuclear warheads and materials worldwide is sustainably secured and accounted for to stringent standards remains a long way away—unacceptably far away, given the urgency of the threat.

Assessing Progress: Against What Goals?

In assessing the progress of programs to improve nuclear security around the world, it is important to be clear about what targets are serving as the basis for judgment. Government programs generally measure their performance against the goals that have been set for them. If a plutonium disposition program, for example, has been assigned the mission of getting rid of 34 tons of excess plutonium, it judges its progress on the basis of how well it is doing on that 34 tons—not on what fraction of the total stockpile of plutonium that may be.

For policymakers, however, it is also important to understand how much of the overall problem to be addressed has been dealt with, regardless of whether all of that problem is within the mission statement of a particular program. Hence it is worthwhile to ask what the *total* scope of the problem is, and how much of that problem has been resolved—and if more than one program is working on parts of that problem, it is worthwhile to combine these programs' progress in one overall metric. This is the approach this chapter will take. It is not meant to downplay the progress these programs have made toward achieving the particular goals they have been set, but only to provide as accurate a picture as possible of the overall progress these programs have made in reducing the threat of nuclear theft and terrorism.

Measuring Progress in Securing Nuclear Stockpiles

The United States and other countries should seek to achieve a very clear goal, as rapidly as practicable: to ensure that every nuclear weapon and every significant cache of weapons-usable nuclear material anywhere in the world is sustainably secured and accounted for, to standards sufficient to defeat the threats that terrorists and criminals have shown they can pose. As noted in the previous chapters, this is a global problem, with

weapons-usable nuclear materials in some 40 countries under widely varying levels of security.

Assessing progress toward meeting this goal is more difficult than it might seem. Within the former Soviet Union, the U.S. government has made available reasonably detailed estimates of the number of sites and buildings with weapons-usable nuclear materials and how many of these have been equipped with various levels of upgrades. Publicly available data on warhead sites and upgrades are also substantial, though less complete. These are useful indicators of progress, but as discussed above, they do not provide full information on all the elements necessary for an effective security system—and do not reflect the security steps Russia has taken on its own, including at sites where U.S.-sponsored upgrades have not been completed.

Outside the former Soviet Union, very little information is publicly available on the number and location of sites where nuclear warheads and the materials needed to make them exist; the current security levels at those sites, as they compare to the threats that terrorists and criminals have shown they can pose in the regions of those facilities; or the quantity and quality of weapons-usable material that exists at those sites. Data have simply not been collected—in classified form or not—on important matters such as pay, morale, and corruption among the staff at nuclear sites around the world, or what procedures are used at different facilities to assess and test the security of sites and what the results of those assessments may have been. As a result, the indicators of global progress provided below have more gaps, and are more uncertain, than the indicators of progress in the former Soviet Union.

Nuclear Security Upgrades: How High Should the Bar be Set?

The basic questions policymakers would like to have answers to are: "How many buildings around the world need security upgrades? How extensive are the upgrades they need? How much will that cost? How long will that take? Can these upgrades be sustained?" Unfortunately, these basic questions do not have open-and-shut answers. The answers depend a great deal on what standards of nuclear security are set as the objective of the effort. Currently, the standards being pursued vary widely from one program to another, for reasons that are more the result of historical accident than rational calculation. The United States is spending roughly $1.5 billion annually on safeguards and security for DOE facilities and activities,[47] most of which goes to protecting sites against a very substantial post-9/11 DBT that reportedly includes squad-sized teams of well-trained outside attackers equipped with sophisticated armaments and equipment, along with multiple well-placed insiders.[48]

U.S.-sponsored upgrades being installed in Russia are intended to defend against

[47] See the "Safeguards and Security Crosscut" in U.S. Department of Energy, *FY 2007 Other Defense Activities*.

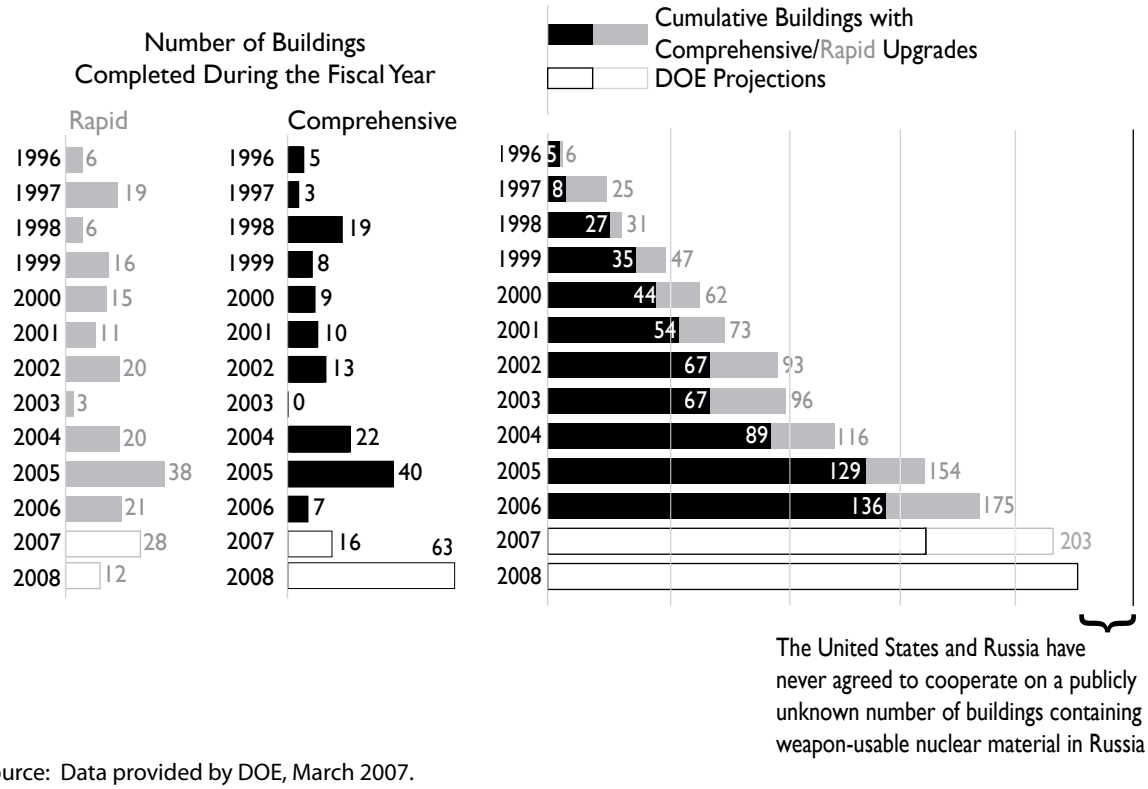
[48] For a discussion of the kinds of armament and equipment included in the new DOE DBT, see Timm, *Security Assessment Report for Plutonium Transport in France*. For non-government summaries of the size of the potential attacking forces included in the threat, see, for example, Project on Government Oversight, "Energy Ups Their DBT, NRC Still Making Excuses" (Washington, D.C.: POGO, 28 September 2004; available at http://pogoblog.typepad.com/pogo/2004/09/energy_ups_thei.html as of 09 July 2007); Peter Stockton, "Vulnerability of Spent Fuel Pools and the Design Basis Threat" (Washington, D.C.: Project on Government Oversight, 10 May 2004; available at http://pogo.org/m/ep/ep-spentfuelpools-NAS-5102004.pdf as of 09 July 2007).

more modest threats (though apparently the threats that U.S. teams are directed to help Russian facilities defend against have been increased since 9/11). In principle Russian sites should be defended against *higher* threats than U.S. sites, rather than the other way around, as both the outsider and insider threats in Russia appear to be substantially higher than they are in the United States, given the ongoing conflict with Chechen separatists there and the huge problem of insider theft and corruption bedeviling Russian society. Security upgrades for the sites with HEU in the non-Russian states of the former Soviet Union were completed before 9/11, with designs intended to protect against significantly lower threats than the upgrades in Russia are designed to cope with. For HEU-fueled research reactors in other countries outside the former Soviet Union, the United States is helping with upgrades to meet very general and vague IAEA recommendations, but also has in mind at least a modest threat that they should be able to defend against when upgrades are completed; in most cases, sites "completed" under this effort could probably only defend against a handful of outside attackers and one insider. Yet in some cases, these countries also face plausible threats from conspiracies of insiders working together and from larger groups of highly capable outside attackers.

Clearly, how many sites are below the bar of effective nuclear security, and how far below they bar they are, depends on where the bar is set. Attempting to ensure that all nuclear weapons and weapons-usable nuclear material worldwide met the latest DOE security standards would require upgrades for a very large fraction of all the world's nuclear facilities, and the upgrades needed would likely be extensive, costly, and time-consuming. (Planned upgrades to meet these requirements at DOE's own facilities are expected to take years and cost hundreds of millions of dollars.) On the other hand, DOE's Global Threat Reduction Initiative (GTRI) program believes that the vast majority of the world's HEU-fueled research reactors already have security in place that meets the IAEA recommendations, leaving only 14 HEU-fueled research reactors worldwide where security upgrades were still underway or planned as of the end of fiscal 2006.[49]

To effectively address the risk of nuclear theft and terrorism, the bar should be set to provide security at a level that can defeat the kinds of overt attacks and covert thefts that terrorists and criminals have shown they can carry out in different regions of the world. UN Security Council Resolution 1540 legally requires all states to have "appropriate effective" security for whatever stockpiles of nuclear weapons and weapons-usable nuclear materials they may have. If the word "effective" is taken literally, it suggests that these security measures must be able to effectively defeat the threats that have been shown to exist. This suggests a security standard that would probably be well above the minimum measures needed to meet current IAEA recommendations, though perhaps below the standard now required of DOE facilities. No reliable measures are yet available to assess how many facilities worldwide would require what level of upgrade to meet this objective. Congress should ask the administration to (a) prepare estimates of how many facilities worldwide require upgrades and how extensive those upgrades would be for various standards of nuclear security; and (b) recommend what nuclear security standards should be pursued.

[49] Data provided by DOE, March 2007 and Septembe 2007..



Source: Data provided by DOE, March 2007.

In the absence of such specific measures of the total amount of global work to be done, this chapter uses indicators relating to the number of buildings and bunkers in the former Soviet Union with various levels of U.S.-sponsored upgrades installed, and a set of measures focused on HEU-fueled research reactors in the rest of the world, intended to provide at least a partial picture of the progress of the global effort.

Securing Metric 1: Security Upgrades on Former Soviet Buildings Containing Nuclear Material

The best available measure—though still a rough one—of both the fraction of the needed security upgrade work that has been finished, and of the fraction of the threat that has been reduced, is the fraction of the buildings where weapons-usable nuclear material is located whose security has been upgraded.[50] The fraction of buildings covered is a better measure than the fraction of materials covered, as a building with ten tons of weapons-usable nuclear material poses little more risk, and requires only modestly more work, than a building with one ton of material.[51] (Previous reports in this series have also reported data on the less informative materials measure, but DOE no longer publishes up-to-date data on this metric.)

[50] Some previous reports in this series relied primarily on measures focusing on materials because this was the only data DOE made publicly available.

[51] Building-level data are also better than site-level data, because a large site with dozens of buildings containing nuclear material may have dozens of different groups that have access to that material, and because the work of improving security at such a huge and multifaceted site is much more time-consuming, complex, and expensive than the work of improving security at a small site with only one building.

From 1993 through the end of FY 2006, comprehensive security upgrades were completed for just over 63% of the 215 buildings in the former Soviet Union believed to contain weapons-usable nuclear material where DOE plans to implement security upgrades.[52] By that time, at least rapid security upgrades had been put in place on 81% of these buildings.[53] Figure 2.1 shows the number of weapons-usable nuclear material buildings with comprehensive or rapid upgrades by year.

The 215 number, however, represents only those buildings where the United States and Russia have agreed to undertake cooperative security upgrades, not the *total* number of buildings with weapons-usable nuclear material in Russia. (Despite considerable success in expanding cooperation in the last few years, there remain some buildings Russia considers too sensitive for such cooperation.) Most importantly, DOE believes that there are "many buildings with hundreds of tons of weapons-usable nuclear material" at the two remaining nuclear warhead assembly/disassembly facilities in Russia (at Lesnoy, formerly Sverdlovsk-45, and Trekhgornyy, formerly Zlatoust-36);[54] these buildings are not included in the 215-building figure.[55] Russia has not agreed to security and accounting cooperation at these sites, and they are not covered in the joint U.S.-Russian nuclear security plan agreed to after the Bratislava summit. Even if Russia changed its mind tomorrow, it would be impossible to complete upgrades at these sites by the end of 2008.

Given their status as the places where nuclear weapons are put together or taken apart, it is likely that without U.S. help Russia has put in place security measures for these sites that are as extensive as those for any other sites in Russia. Nevertheless, at other highly sensitive Russian nuclear weapons complex facilities where U.S. experts have been able to visit, it has generally not taken long for U.S. and Russian experts to agree on an extensive set of needed upgrades; whether the same would be true if cooperation began at these two sites is simply unknown.

Russia had made clear from the outset of MPC&A cooperation that these sites would be too sensitive to permit U.S. access. In the 1990s the two sides negotiated

[52] Data provided by DOE, March 2007. DOE's estimate of the total number of buildings in the former Soviet Union where upgrades will be implemented changes over time, as DOE learns more about particular buildings, and as the situation on the ground changes (for example, when nuclear material is removed from particular buildings or brought to new buildings for the first time). In the budget justifications for FY2007, DOE estimated that there were "approximately 195" buildings with weapons-usable nuclear material in the former Soviet Union. U.S. Department of Energy, *FY 2007 Congressional Budget Request: National Nuclear Security Administration--Defense Nuclear Nonproliferation*, vol. 1, DOE/CF-002 (Washington, D.C.: DOE, 2006; available at http://www.cfo.doe.gov/budget/07budget/Content/Volumes/Vol_1_NNSA.pdf as of 10 July 2007), p. 514. Several months later, in the data provided to our group, this figure had increased to 230. By the time the FY 2008 budget justification was prepared, this figure had declined again, to 210 buildings. See U.S. Department of Energy, *FY 2008 NNSA Budget Request*, p. 474. This was also the figure DOE provided to the Government Accountability Office for its report U.S. Congress, *Nuclear Nonproliferation: Progress Made in Improving Security at Russian Nuclear Sites, but the Long-Term Sustainability of U.S.-Funded Security Upgrades Is Uncertain*. By the time of the data DOE provided in March 2007, their estimate had increased slightly again, to 215 buildings. The uncertainty is in the precise number of buildings containing weapons-usable nuclear material at some of the large sites in Rosatom's nuclear weapons complex.

[53] U.S. Department of Energy, *FY 2007 Defense Nuclear Nonproliferation Budget Request*, p. 514.

[54] The quote is from U.S. Congress, *Nuclear Nonproliferation: Progress Made in Improving Security at Russian Nuclear Sites, but the Long-Term Sustainability of U.S.-Funded Security Upgrades Is Uncertain*, p. 16.

[55] Clarification provided by DOE, May 2007.

an agreement that provided arrangements for cooperation in improving security and accounting at these sites without direct access by U.S. personnel. But soon after the agreement was signed, the United States effectively reneged on it, demanding direct on-site access for any further contracts at any site in Russia. The result was years of delay for facilities in Russia's nuclear weapons complex, and no cooperation at all at these two sites thought to house huge quantities of nuclear weapons material.[56]

It is very likely that some of the large number of buildings at other nuclear weapons complex sites that are not receiving security upgrades, and that U.S. experts have not visited, also contain weapons-usable nuclear material that Russia considers particularly sensitive. If so, then these are also not included in the 215 figure, or in the post-Bratislava plan. For example, after an operational review at Seversk in the mid-1990s, one of the reviewers reported publicly that one building there held containers for 23,000 "pits" for nuclear weapons.[57] While the United States is financing security upgrades for a substantial number of buildings at Seversk, no building with such an immense stockpile of weapons components has ever been discussed.[58]

The total number of buildings with weapons-usable nuclear material that are not included on the list of 215 is not publicly known. Assuming, conservatively, that there are 10 such buildings at each of the two major weapons assembly and disassembly sites, and 10 more elsewhere, there would be 245 total buildings with weapons-usable in the former Soviet Union. If that is the case, then the percentage of the total that had received comprehensive upgrades by the end of FY 2006 would be in the range of 55%; the buildings with at least rapid upgrades completed by the end of FY 2006 amount to just over 70% of that larger total.

Rate of progress. FY 2006 was a slow year for completing comprehensive upgrades, with seven additional buildings completed during the year (compared to 40 the year before), bringing the total completed to 136. Rapid upgrades were completed on 21 buildings in FY 2006, down from 35 the year before. This slowdown was expected (and was reflected reasonably accurately in last year's projections).[59] DOE projects a somewhat higher pace for completing both rapid and comprehensive upgrades in FY 2007 (though not matching FY 2005 in either case), and then an extremely high pace for completing comprehensive upgrades in 2008.

[56] For a contemporaneous account of this episode, see Oleg Bukharin, Matthew Bunn, and Kenneth N. Luongo, *Renewing the Partnership: Recommendations for Accelerated Action to Secure Nuclear Material in the Former Soviet Union* (Washington, D.C.: Russian American Nuclear Security Advisory Council, 2000; available at http://bcsia.ksg.harvard.edu/BCSIA_content/documents/mpca2000.pdf as of 09 July 2007). See also Matthew Bunn, "Cooperation to Secure Nuclear Stockpiles: A Case of Constrained Innovation," *Innovations* 1, no. 1 (2006; available at http://bcsia.ksg.harvard.edu/BCSIA_content/documents/INNOV0101_CooperationtoSecureNuclearStockpiles.pdf as of 09 July 2007).

[57] Valerii F. Menshikov, "On the Situation with Storage of Plutonium and Enriched Uranium in Tomsk-7," *Yaderny Kontrol*, no. 2 (February 1995).

[58] Interview with DOE official, May 2007.

[59] For a chart showing last year's DOE estimates of how many buildings had been completed and would be completed in the future, see Matthew Bunn and Anthony Wier, *Securing the Bomb 2006* (Cambridge, Mass.: Project on Managing the Atom, Harvard University, and Nuclear Threat Initiative, 2006; available at http://www.nti.org/securingthebomb as of 07 August 2007), p. 50.

DOE and Russia have agreed on the goal of completing omprehensive upgrades at the 215 buildings by the end of 2008. (Upgrades were completed years ago for the non-Russian sites of the former Soviet Union.) But for several years, DOE's estimate of the fraction of the work to be done in the final year has increased each year, suggesting the challenges in meeting the 2008 goal. Overall, however, it appears likely that security and accounting upgrades for the buildings covered in the U.S.-Russian joint nuclear security plan agreed to after the 2005 Bratislava summit will either be completed by the deadline or within a year or two thereafter. But that will leave a significant number of buildings, believed to contain hundreds of tons of weapons-usable nuclear material, not yet covered by any U.S.-sponsored upgrades.[60]

Other security and accounting improvements. In addition to installing upgraded security and accounting equipment at buildings, U.S. and other international assistance programs have helped with a wide range of other improvements as well. These have included, among other items, training for security and accounting personnel and for nuclear guards; help with strengthening nuclear security and accounting regulation; secure trucks and railcars for transporting nuclear material; efforts to consolidate and blend down nuclear material; work on promoting strong security cultures at selected sites. Several of these efforts have made significant progress, though it is more difficult to measure accurately. The Government Accountability Office reports that these other efforts accounted for $493.9 million of the $1.3 billion DOE spent on nuclear material upgrades in Russia and other countries through the end of FY 2006.[61] In addition, the Department of Defense (DOD) financed the construction of a huge fortress for storage of weapons-usable nuclear material, the Mayak Fissile Material Storage Facility. After years of delays, Russia began loading the facility in July 2006. As of the spring of 2007, however, transparency arrangements for the facility had not been finalized.[62]

Sustainability. After all the planned upgrades have been installed, DOE expects a four-year period of continued cooperation to ensure sustainability, during which U.S. assistance will phase down, and Russia's investments, DOE hopes, will increase. (Congress has mandated that DOE attempt to put in place a security system in Russia that is sustained with only Russian resources by January 1, 2013.[63]) DOE and Russia's Federal Agency for Atomic Energy (Rosatom) reached a major agreement on sustaining upgrades at Rosatom sites in April 2007, laying out the tasks that need to be accomplished at each site and which party would take responsibility for each one.[64] There is not a similar comprehensive plan for non-Rosatom

[60] It is not quite correct that the weapons assembly/disassembly facilities have had no U.S.-sponsored upgrades at all. In the mid-to-late 1990s, the United States provided portal monitors for installation and use at these facilities, without any U.S. access to these sites.

[61] U.S. Congress, *Nuclear Nonproliferation: Progress Made in Improving Security at Russian Nuclear Sites, but the Long-Term Sustainability of U.S.-Funded Security Upgrades Is Uncertain*, p. 12. For a useful description of these other efforts, see pp. 48-54 of the same report. See also U.S. Department of Energy, *2006 MPC&A Strategic Plan*.

[62] U.S. Department of Defense, *Cooperative Threat Reduction Annual Report to Congress: Fiscal Year 2008* (Washington, D.C.: U.S. Department of Defense, 2007), p. 21.

[63] U.S. House of Representatives, *National Defense Authorization Act for Fiscal Year 2003*, 108th Congress, 2nd Session, Public Law 107-314 (2002; available at http://thomas.loc.gov/cgi-bin/query/z?c107:H.R.4546.ENR: as of 09 July 2007).

[64] U.S. Department of Energy, "U.S. & Russia Agree to Sustain Security Upgrades." This was supplemented by an interview with a U.S. national laboratory official, January 2007.

sites, but site teams are seeking to work out sustainability plans on a site-by-site basis. Ultimately, as discussed in Chapter 4, sustaining effective security for the long haul will require Russia to assign enough money and people to get the job done—which has not happened yet—and put in place effective, and effectively enforced, nuclear security rules.

Securing Metric 2: Security Upgrades on Russian Sites Containing Warheads

Fraction accomplished. DOD and DOE are both working with Russian counterparts to install modern security systems at Russian nuclear warhead sites. It is more difficult to assess progress in installing these upgrades than it is for nuclear materials, as neither the U.S. nor the Russian government has published current, detailed estimates of how many nuclear warheads exist in Russia, at how many sites. Even the basic question of what fraction of Russia's warhead sites are covered by current U.S. plans for warhead security upgrades can only be partially answered from publicly available data.[65]

Between them, DOE and DOD now plan to help with security upgrades at 97 Russian nuclear warhead sites (73 DOE and 24 DOD); of these, 41 are permanent storage sites and 56 are temporary sites such as warhead handling areas or points where warheads are stored temporarily when being transferred from rail to truck or from one rail line to another (known as rail transfer points).[66] Subsequent to the Bratislava summit, the United States and Russia agreed on upgrade cooperation and on access arrangements for 15 of these 97 sites.

The total number of warhead sites in Russia is not publicly known, but is somewhat larger. While DOD has asserted that the agreed list of sites for upgrades includes "all permanent storage locations that contain strategic or tactical nuclear weapons,"[67] there are a small number of additional sites that may or may not contain warheads where Russia has previously requested assistance and the United States has declined to provide it, for policy reasons.[68] More importantly, there are a larger number of temporary warhead locations (such as warhead handling areas at bases, or rail transfer points) where the two sides have not agreed to cooperate on security upgrades. In January 2003, the administration decided that in most cases it would not provide further security upgrade assistance to such sites, to avoid contributing to Russia's operational nuclear capabilities.[69] Prior to the Janu-

[65] I am grateful to Charles L. Thornton of the University of Maryland, and to several U.S. government officials, for helping me better understand the limited publicly available information.

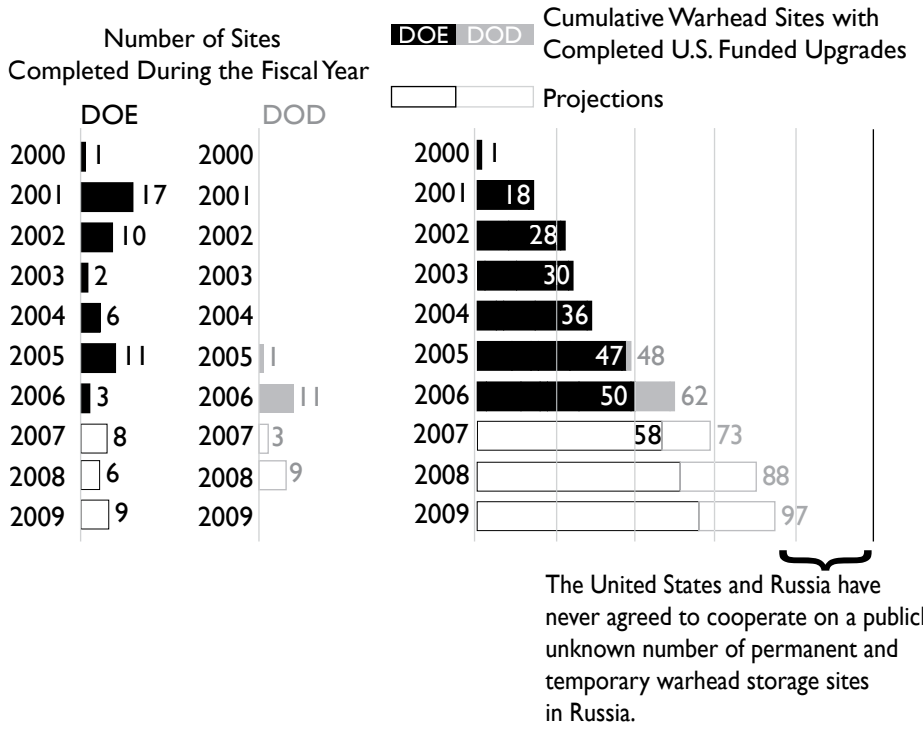
[66] U.S. Congress, *Nuclear Nonproliferation: Progress Made in Improving Security at Russian Nuclear Sites, but the Long-Term Sustainability of U.S.-Funded Security Upgrades Is Uncertain*, p. 19.

[67] U.S. Department of Defense, *Cooperative Threat Reduction Annual Report to Congress: Fiscal Year 2007* (Washington, D.C.: U.S. Department of Defense, 2006), p. 28.

[68] DOE has declined to offer assistance for three naval sites, apparently because there should not be warheads there if Russia is fulfilling its pledges under the 1991–1992 Presidential Nuclear Initiatives. Russian requests for assistance at these three Navy sites provoked considerable concern and suspicion within the U.S. government. Interviews with DOE, DOD, and national laboratory officials, 2003 and February–March 2004. The U.S. government has apparently also declined to support upgrades at a site in the Russian enclave of Kaliningrad (where the U.S. government believes no warheads should be located), a site near the Black Sea (which should not have warheads unless Russia were re-nuclearizing the Black Sea Fleet), and possibly others. (Interview with U.S. contractor , October 2003.)

[69] U.S. Congress, General Accounting Office, *Weapons of Mass Destruction: Additional Russian Cooperation Needed to Facilitate U.S. Efforts to Improve Security at Russian Sites*, GAO-03-482 (Washington,

Figure 2.2:
Warhead Sites with Security Upgrades



Source: U.S. Department of Energy, FY 2008 *Congressional Budget Request: National Nuclear Security Administration* (Washington, D.C.: DOE, 2007), p. 474, and U.S. Office of Management and Budget, Cooperative Threat Reduction Assessment (Washington, D.C.: OMB, 2007).

ary 2003 decision, DOD had considered providing a package of security upgrades for dozens of temporary warhead facilities, of which only a fraction are covered by the current agreed list of sites for upgrades.[70] There is also the entire category of front-line tactical warhead sites, which is not covered in current plans. If Russia has fully implemented the 1991-1992 U.S.-Russian nuclear initiatives, these should no longer have warheads in them, but a number of them continue to exist, some of the units continue to train for nuclear missions, and U.S. officials have occasionally asserted that Russia has not fully implemented its side of these initiatives.[71]

It thus appears that the total number of warhead sites, including both permanent and temporary sites, but not counting the front-line tactical sites that may no longer have warheads, is likely to be in the range of 110-130, leaving roughly 10-30 sites not yet subject to cooperation.

During FY 2006, security upgrades were completed at 14 warhead sites in Russia,

D.C.: GAO, 2003; available at http://www.gao.gov/new.items/d03482.pdf as of 24 May 2007), pp. 33-34.

[70] Personal communication with U.S. contractor, May 2005.

[71] In September 1991, President George H.W. Bush and then-Soviet President Mikhail Gorbachev each unilaterally announced that they would eliminate nuclear weapons from naval surface vessels, pull back most tactical weapons to central storage sites and destroy many of them, and take certain steps to reduce strategic weapons and their alert rates as well. In early 1992, Russian President Boris Yeltsin confirmed and extended Gorbachev's commitments. For a discussion of the controversy over Russian fulfillment of its commitments, see Wade Boese, "U.S., Russia Debate Tactical Nuclear Arms," *Arms Control Today* (November 2004; available at http://www.armscontrol.org/act/2004_11/Tactical_Nukes.asp as of 09 July 2007). I am grateful to Charles L. Thornton for making this point to me.

bringing the total completed to 62.[72] This represents 64% of the 97 sites planned, and roughly 50% of the total number of warhead sites.[73] The work in FY2006 included completion of the last two of Russia's Navy warhead sites; security upgrades have now been finished for all Russian Navy nuclear warhead and weapons-usable nuclear material sites.[74] Figure 2.2 shows the number of warhead sites completed by year in the past, and projected for the future, by DOE and DOD.[75]

Rate of progress. During FY 2006, DOE completed upgrades on three additional warhead sites, and DOD completed upgrades at 11 sites (a banner year for DOD, which had previously completed upgrades at only one site). This raised the estimated fraction of the total number of warhead sites with completed upgrades from approximately 40% to roughly 50%. The three sites DOE completed fell short of its target of six, "due to unforeseen weather, technical, and contractor access problems"; the other three are slated to be completed during the current fiscal year.[76] Between them, DOE and DOD intend to complete upgrades for 11 more sites in FY 2007, 15 more in FY 2008, and nine in FY 2009 (presumably in the first months of the fiscal year, in order to meet the deadline of the end of calendar 2008 for completing these upgrades). This appears possible, though they will face a variety of "challenges" in meeting this schedule, as the Government Accountability Office has described.[77]

Other security and accounting improvements. In addition to equipment upgrades at warhead sites, the United States has provided a wide range of additional assistance to improve security for nuclear warheads in Russia. Perhaps most important, the United States has provided secure railcars, "supercontainers," and other equipment to ensure that warhead transports are secure, and is paying the costs for secure warhead transports from deployment sites back to dismantlement or storage locations. DOD sponsored 47 such trainloads of warheads during FY 2006, carrying an estimated 15-20 warheads on each trip; by the end of FY 2006, DOD had sponsored a total of 328 such trips, moving roughly 5,000-6,000 Russian nuclear warheads to storage facilities or to

[72] For data on the warhead sites completed by DOE, see U.S. Department of Energy, *FY 2008 NNSA Budget Request*, p. 474. For data on the warhead sites completed by DOD, see U.S. Office of Management and Budget, *Cooperative Threat Reduction Assessment* (Washington, D.C.: OMB, 2007; available at http://www.whitehouse.gov/omb/expectmore/detail/10003219.2006.html as of 09 July 2007).

[73] This estimate uses 120 sites, the midpoint of the 110-130 range, as the baseline, and is rounded to the nearest 5%, to avoid giving a false sense of precision.

[74] U.S. Department of Energy, *FY 2008 NNSA Budget Request*, p. 475.

[75] Data on the warhead sites completed by DOE provided by DOE, May 2006, updated with U.S. Department of Energy, *FY 2008 NNSA Budget Request*, p. 474. For data on the warhead sites completed by DOD, see U.S. Office of Management and Budget, *Cooperative Threat Reduction Assessment*. It is important to note that many of the warhead sites where DOE has done upgrades will only receive "rapid" upgrades and not the full suite of comprehensive upgrades, either because they are considered not to pose enough risk to require comprehensive upgrades or because of the policy on upgrades at operational warhead-handling sites. As of the end of FY 2005, for example, 31 of the 47 warhead sites DOE had "completed" had received only rapid upgrades, not comprehensive upgrades. As of mid-2006, DOE expected that 6 more warhead sites would receive only rapid upgrades by the completion of the upgrade effort, for a total of 37 warhead sites in this category. No data are publicly available on whether any of the DOD warhead sites are slated to receive less than the full suite of comprehensive upgrades.

[76] U.S. Department of Energy, *FY 2008 NNSA Budget Request*, p. 475.

[77] U.S. Congress, *Nuclear Nonproliferation: Progress Made in Improving Security at Russian Nuclear Sites, but the Long-Term Sustainability of U.S.-Funded Security Upgrades Is Uncertain*, p. 19.

dismantlement.[78] DOD has also financed a Security Assessment and Training Center (SATC) at Sergeyev Posad, which provides a site for training nuclear weapons security personnel and for testing and assessing nuclear weapons security equipment; the United States has also financed the Kola Technical and Training Center, largely for the Russian Navy (which must protect both weapons-usable nuclear material and nuclear warheads), and DOD is planning to finance an additional center in the Far East.[79] A project to provide an Automated Inventory Control and Management System (AICMS) to 19 warhead-related sites in Russia was completed in FY 2006.[80] Further, the United States has provided equipment and training to improve Russia's personnel reliability program for individuals with nuclear weapon responsibilities; guard force equipment and training (another project completed in FY 2006); and a variety of emergency response equipment.[81]

Sustainability. As with nuclear material sites, DOE and DOD are both discussing with Russia the need to sustain high levels of security at nuclear warhead storage sites after U.S. assistance comes to an end. Both DOE and DOD plan to provide assistance with procedures and regulations, training and maintenance centers, and warranties and spare parts for individual sites for a limited period. They have not yet reached agreement with Russia on access that DOE and DOD believe will be needed to confirm that site-level sustainability assistance is used appropriately at warhead sites, which could pose an obstacle.[82] In general, there has been significantly less progress in working out a joint approach to ensuring that high levels of security are sustained after U.S. assistance ends in the case of warhead sites than there has been for Rosatom nuclear material sites. While DOE plans to continue sustainability assistance for warhead sites until 2013, as it plans for nuclear material sites, DOD plans only three years of sustainability assistance after completing upgrades in 2008.[83]

Global Measures

As discussed earlier, no comprehensive measures of progress in improving the global nuclear security picture are available. There are some data available, however, concerning research reactors with HEU fuel, which pose some of the most important risks of nuclear theft—in the former Soviet Union and around the world. This report will therefore use improvements at HEU-fueled research reactors as a rough indicator of progress in addressing the global nuclear security risk.

There are essentially three steps to be taken to improve security at these sites: first, upgrading their security to meet IAEA physical protection recommendations, as modest as those may be; second,

[78] U.S. Department of Defense, *FY 2007 CTR Annual Report*, p. 3.

[79] U.S. Department of Defense, *FY 2007 CTR Annual Report*, p. 19.

[80] U.S. Department of Defense, *FY 2007 CTR Annual Report*, p. 18.

[81] U.S. Department of Defense, *FY 2007 CTR Annual Report*, p. 18. For an overview of the DOD warhead security programs (now somewhat out of date), see William Moon, "CTR Russian Weapons of Mass Destruction Security Program," paper presented at National Defense Industries Association Security Division Symposium and Exhibition, Reston, Vir., 27 June 2002 (available at http://www.dtic.mil/ndia/2002security/moon.pdf as of 29 May 2007).

[82] U.S. Congress, *Nuclear Nonproliferation: Progress Made in Improving Security at Russian Nuclear Sites, but the Long-Term Sustainability of U.S.-Funded Security Upgrades Is Uncertain*, pp. 29-30.

[83] U.S. Congress, *Nuclear Nonproliferation: Progress Made in Improving Security at Russian Nuclear Sites, but the Long-Term Sustainability of U.S.-Funded Security Upgrades Is Uncertain*, pp. 29-30.

upgrading their security to be able to defeat threats that are plausible at those sites, given the level of criminal and terrorist activity in that country and the quantity and quality of the material at the site (a higher standard, in most cases); and third, removing the HEU entirely (which requires either converting the reactor to use non-weapons-usable LEU fuel or shutting it down as a preliminary step before HEU removal). The discussion below provides measures of progress on all three of these steps.

Securing Metric 3: Global Operating HEU Reactor Sites Upgraded to Meet IAEA Security Recommendations

Many HEU-fueled research reactors have security measures that meet IAEA recommendations without any U.S. or other assistance, as most countries follow these recommendations. In particular, for decades, the United States by law has been seeking to ensure that countries with U.S.-obligated nuclear material protect it in a way consistent with these recommendations. Nevertheless, in the last 15 years, a number of countries have been judged to have measures in place that do not fully comport with the recommendations or have requested assistance in meeting these recommendations for HEU-fueled reactors. The U.S. government, other international donors, and the IAEA, working together, have made substantial progress in upgrading these sites to meet the IAEA recommendations.

Within the U.S. government, several programs are responsible for different portions of this work. DOE's International Nuclear Materials Protection and Cooperation program currently handles security upgrades at sites in the former Soviet Union, China, and Pakistan (and would handle cooperation with India if such cooperation began). DOE's GTRI program is charged with upgrading security where needed at HEU-fueled research reactors in other foreign countries. Another part of DOE is responsible for occasional visits to countries with U.S.-origin nuclear material and facilities, to confirm that they are providing physical protection consistent with IAEA recommendations, as called for by U.S. law. The State Department provides diplomatic support for these cooperative programs, and leads the delegations that negotiate agreements such as the amendment to the physical protection convention.[84] A number of other donor states have also contributed more modestly to upgrades for a number of these sites, and the IAEA's Office of Nuclear Security, which helps organize international nuclear security peer reviews, has helped to coordinate upgrade assistance from various donors.

As of the end of FY 2006, the United States (and other countries in several cases) had provided assistance to upgrade security at 19 HEU sites outside of Russia to the level of the IAEA recommendations—11 in the non-Russian states of the former Soviet Union (representing 100% of the HEU sites there), and 8 more elsewhere.[85] There are 14 more HEU sites that DOE believes require upgrades to meet the most recent IAEA recommendations, for a total of 33 such sites outside of Russia and the United States. The sites in the former Soviet Union, however, like the sites in Russia, are already counted in the earlier measure of buildings with weapons-usable materials with either rapid or comprehensive upgrades. If those sites are excluded from this total (to avoid double-counting), then by the end of FY2006, just under 40% of the 22 HEU sites judged to require upgrades to meet the IAEA

[84] In fact, the situation is slightly more complicated than this. If a particular training or upgrade program goes forward under an IAEA rubric, U.S. participation is led by yet another part of DOE, the group responsible for international safeguards.

[85] Data provided by DOE, March and August 2007.

Table 2.1:
Global HEU-Fueled Research Reactors Upgraded to IAEA Recommendations

Category	Total	Needed Upgrades	Upgraded to IAEA Recs	Still to be Upgraded
Russia Civil	52	52	55	0
Russia Military	12	12	12	0
Non-Russian FSU	8	8	8	0
Non-Russian FSU other sites	5	5	5	0
U.S. NRC-Regulated	8	8	0	8
U.S. DOE+DOD	11	0	0	0
Other Military	5	0	0	0
Other Civilian	43	19	5	14
Other Upgraded HEU Sites	3	3	3	0
Total	**147**	**107**	**85**	**22**
Percent of Needed Upgrades			*80*	***20***

Source: Author's estimates, based on data from Ole Reistad, personal communication, June 2007.

recommendations had been completed. (Four more of these sites had been completed by mid-2007.)[86]

If one takes a more global perspective, including all the HEU-fueled reactors worldwide (including those in the former Soviet Union and the United States), the picture looks still better, because of the large number of HEU-fueled reactors in Russia and the other states of the former Soviet Union which have been upgraded to levels that meet or exceed the IAEA recommendations.

The data for such a global perspective are somewhat uncertain. The most recent estimates indicate that there are some 140 operating HEU-fueled research reactors worldwide.[87] This is an imperfect measure of the size of the task: there are a number of HEU sites that are not research reactors, and an unknown number of research reactors that shut down without converting but still have HEU on-site;[88] in some cases the publicly available data focuses on sites, and there may be several research reactors at a single site, creating some uncertainties in estimates of the total fraction of the job accomplished; and the total is constantly changing as HEU-fu-

[86] Data provided by DOE, July 2007.

[87] A listing provided by DOE in March 2007, for example, includes 207 research or icebreaker reactors, of which 46 were converted and two were shut down, and 15 were icebreaker reactors (important to address, but a different category from research reactors), leaving 144 research reactors still operating with HEU. Similarly, data compiled by Ole Reistad (Institute of Physics, University of Science and Technology at Trondheim, and Norwegian Radiation Protection Authority) includes 146 reactors operating with HEU fuel, of which five are plutonium or tritium production reactors, one is a commercial reactor, and one is plutonium-fueled, leaving 142 that are research reactors operating with HEU fuel. Personal communication from Ole Reistad, June 2007. In a forthcoming report, Reistad and colleagues offer modified data reflecting ongoing conversions and shutdowns. See Ole Reistad, Morten Bremer Maerli, and Styrkaar Hustveit, *Non-Explosive Nuclear Applications Using Highly Enriched Uranium—Conversion and Minimization Towards 2020* (Princeton, N.J.: International Panel on Fissile Materials, 2007). Both the DOE list and the Reistad et al. list are larger than the 135 HEU-fueled research reactors estimated in my previous report, despite the conversion of several HEU-fueled research reactors in the interim; this is because of additional information that DOE has acquired from site visits and discussions, and that non-government researchers have pieced together, which has made it possible to identify more reactors using HEU. As additional reactors convert or shut down, the total will decline back to, and eventually below, 135.

[88] In order to give full credit for upgrades performed to date, I have added sites such as these where upgrades have been performed both to the total for the scope of the job and to the number for the portion of the job already accomplished.

eled reactors convert to LEU or shut down (or, rarely, start up). By one estimate, there may have been roughly 50% more HEU-fueled research reactors operating in 1992, when threat reduction programs largely began, than there are today. Here, however, I will focus on those that are still operating with HEU today.[89]

HEU-fueled reactors in the former Soviet Union. The most extensive upgrades of security at HEU-fueled research reactors over the past fifteen years have taken place in Russia and the other states of the former Soviet Union. By one estimate, there are some 64 HEU-fueled research reactors in Russia (the largest number in any single country), of which 52 are civilian and 12 are military.[90] Although comprehensive data are not publicly available on the state of security at these reactors in 1992, when threat reduction programs got underway, given what is known it seems very likely that few, if any, of the civilian facilities in Russia fully met the IAEA physical protection recommendations. All of the civilian facilities in Russia have now been upgraded to meet or exceed the IAEA recommendations, either with American, international, or Russian funds.

Most of the 12 military facilities are in closed nuclear cities. There, many of them may have already, in 1992, complied with IAEA recommendations for fences or other strong barriers, intrusion detectors, and 24-hour guard forces. For a rough estimate, I assume that the 12 military reactors did not require upgrades to meet the IAEA recommendations.

In addition, there are 11 HEU sites in the other states of the former Soviet Union where the United States has provided assistance with security upgrades—though these include sites with operating HEU-fueled research reactors, sites with shut-down research reactors, and related sites without research reactors. As removal efforts proceed, some of the sites that received upgrades now either have no HEU or only very modest quantities of HEU, but to be complete, these upgrades are counted here against the total. By one estimate, these 11 sites now contain a total of eight operational HEU-fueled research reactors; they also include five sites that either were not research reactors in the first place or are HEU-fueled research reactors that are now shut down.[91]

[89] Author's estimates, based on data from Reistad, personal communication, June 2007.

[90] Reistad, personal communication, June 2007.

[91] The five sites that do not currently have operational HEU-fueled research reactors are: the Nuclear Research Center near Salaspils in Latvia (which has a shut-down HEU-fueled reactor, and from which all unirradiated HEU was removed in May 2005); the Kharkiv Institute of Physics and Technology in Ukraine (which has never had a research reactor, but has an estimated 75 kilograms of HEU in oxide powder, and is working on a subcritical assembly that would use some of this material); the Sevastopol Institute of Nuclear Energy and Industry (which has shut-down HEU-fueled training reactors), also in Ukraine; the Ulba Metallurgical Plant at Ust-Kamenogorsk in Kazakshtan (a fuel fabrication facility which no longer has HEU on-site [largely because of Project Sapphire in 1994, which airlifted nearly 600 kilograms of HEU from this facility], though it now has an HEU-to-LEU blending capacity installed, with help from the private Nuclear Threat Initiative [NTI], which paid to have tons of HEU from the BN-350 blended to LEU there); and the BN-350 Fast Breeder Reactor at Aqtau, also in Kazakhstan (which is no longer operating and no longer has fresh HEU on-site -- because of the NTI-sponsored blending just mentioned -- though the spent fuel contains some three tons of better-than-weapon-grade plutonium, and may contain some material which remains barely above the 20% enrichment line that defines HEU). The non-Russian former Soviet sites with operating HEU-fueled research reactors include: the Kiev Institute of Nuclear Research in Ukraine (which still has an operating HEU-fueled research reactor); the Institute of Atomic Energy at Kurchatov in Kazakhstan (the former Semipalatinsk test site, which still has two operating HEU-fueled reactors); the Institute of Nuclear Physics in Alatau, also in Kazakhstan (which still has one operating HEU-fueled reactor, along with fresh HEU on-site); the Institute

Non-U.S. HEU-fueled reactors beyond the former Soviet Union. By the end of FY 2006, security upgrades sponsored by the United States (often with contributions from other donors as well) had been completed for 8 HEU-fueled research reactors outside the former Soviet Union.[92] Three of these are not currently operating with HEU.[93] DOE believes that another 14 HEU-fueled research reactors beyond the former Soviet Union still require security upgrades (though by mid-2007, upgrades had been completed at five more of these facilities, leaving only nine more to go).[94]

U.S. HEU-fueled research reactors. With the conversion of the reactors at Texas A&M and the University of Florida in 2006, and the conversion of the reactor at Purdue University expected in 2007, there will be 19 remaining HEU-fueled research reactors in the United States, of which 8 are licensed by the NRC and the remainder are controlled either by DOE or DOD.[95] As noted earlier, while DOE and DOD impose stringent security requirements, research reactors regulated by NRC are exempt from most of the security requirements NRC imposes on other sites with HEU. Ironically, although since 1978 the United States has been required by law to insist that other countries using U.S.-origin nuclear material meet IAEA security recommendations, NRC-regulated HEU-fueled research reactors in the United States are subject to security regulations that are significantly weaker than the IAEA recommendations.[96] Thus,

of Nuclear Physics and the Photon facility in Uzbekistan (each of which still has one operational HEU-fueled research reactor, though both now only have very modest quantities of HEU on-site); and the Joint Institute for Power and Nuclear Research in Sosny, Belarus (which has an operational sub-critical assembly using HEU, along with a shut-down research reactor and shut-down critical assemblies). Data on upgrade sites provided by DOE, December 2005. Data on still-operating HEU fueled research reactors at these sites from Reistad, personal communication, June 2007, and Reistad, Maerli, and Hustveit, *Minimizing HEU-Fuelled Non-Explosive Applications*.

[92] Data provided by DOE, March 2007.

[93] Security upgrades were completed for a research reactor in Romania that was not operating, though HEU remained on-site; security upgrades were also completed for another research reactor in Romania and one in Greece that have since converted to LEU, so no longer count as operating HEU-fueled research reactors. Data provided by DOE, December 2005 and March 2007.

[94] Data provided by DOE, July and August 2007. It appears, however, that some of the reactors upgrades in fiscal 2007 were LEU-fueled facilities requiring only modest security measures, not HEU-fueled facilities.

[95] Reistad, personal communication, June 2007, and Reistad, Maerli, and Hustveit, *Minimizing HEU-Fuelled Non-Explosive Applications*.

[96] For "Category I" nuclear material (including 5 kilograms or more of U-235 in HEU), the IAEA recommendations suggest that the material be in an "inner area" whose ceiling, walls, and floors provide a "penetration delay" against any unauthorized attempt to remove nuclear material, which should be within a "protected area" that has a physical barrier around it (usually a fence outside the building, though the building walls can be the barrier if they are of specially strong construction) and has intrusion detectors. The IAEA recommendations also call for a 24-hour guard force, which should either be armed or measures should be taken to compensate for their lack of armament (such as barriers providing more delay time for armed off-site response forces to arrive); in addition, they urge each country to establish a DBT that would be the basis for its physical protection system, and do not mention any exemption for research reactors. See International Atomic Energy Agency, *The Physical Protection of Nuclear Material and Nuclear Facilities*, INFCIRC/225/Rev.4 (Corrected) (Vienna: IAEA, 1999; available at http://www.iaea.or.at/Publications/Documents/Infcircs/1999/infcirc225r4c/rev4_content.html as of 10 July 2007). NRC rules exempt research reactors from most NRC Category I requirements, including the requirement to defend against any particular DBT. (This exemption, granted in the late 1970s when NRC first required facilities to be able to defend against a specific DBT, was intended to be temporary, in the expectation that the HEU-fueled reactors would soon convert to LEU; NRC ordered the reactors to do so in 1986, as soon as appropriate LEU fuel and DOE funding to pay for the conversion were available—but until recently, DOE did not provide the necessary funding, so 20 years after

these reactors should be added to the list of facilities that would require upgrades to meet the level of security recommended by the IAEA.

The Global Picture. All told, then, it appears that roughly 77 operational HEU-fueled research reactors and eight other civilian HEU sites outside of Russia were upgraded to meet IAEA recommendations between 1992, when cooperative threat reduction programs began, and the end of FY 2006, for a total of approximately 85 research reactor or related HEU sites. Table 2.1 breaks down this estimate by the categories of facilities described in the text. With 14 sites remaining outside the former Soviet Union (as of the end of FY 2006), and eight more in the United States, the estimated 85 upgraded HEU-fueled research reactors or related sites represent roughly 80% of the total global number of operational HEU-fueled research reactors requiring such upgrades. These estimates contain significant uncertainties, particularly in the case of the reactors within Russia.

The 80% figure may overstate the total fraction of the problem that has been addressed. First, there may be additional sites, not yet identified, that do not have all the measures recommended in the latest revision of the IAEA recommendations. Second, until recently DOE had assumed that all irradiated HEU was self-protecting according to the IAEA standards, and therefore required few security measures.[97] Hence, any HEU-fueled research reactor that had less than 5 kilograms of U-235 contained in fresh, unirradiated HEU (the minimum considered a "Category I" quantity requiring the highest level of protection in the IAEA recommendations) was not considered to require many security measures; many HEU-fueled research reactors have smaller amounts of fresh fuel on hand at any time. But DOE now recognizes that the assumption that the irradiated fuel is self-protecting was incorrect, in many cases: most of the world's irradiated HEU research reactor fuel is *not* self-protecting, even by the IAEA standard of material emitting 100 rads per hour at a distance of one meter (a standard which itself needs to be fundamentally reconsidered in a world of suicidal terrorists).[98] There may

the NRC conversion order and nearly 30 years after the NRC exemption was granted, there are still nine HEU-fueled reactors regulated by the NRC.) The NRC does require that Category I material at a research reactor be inside a "material access area" comparable to the IAEA "inner area", which should be within a "protected area"—but there is no requirement for fences outside the building where the reactor is located, no requirement for intrusion detection except within the material access area itself, and no requirement for any armed guards or any compensating measures in the case of unarmed guards. Most NRC-licensed research reactors are not subject to the NRC rules for Category I research reactors in any case, because the only substantial amounts of HEU they have on hand are irradiated. While the IAEA recommendations indicate that material emitting 100 rads per hour at one meter can be reduced from Category I to Category II (for which a protected area whose physical barrier is equipped with intrusion detectors is still suggested), NRC rules exempt such irradiated material from virtually all physical protection requirements. For a remarkable exposé of security for NRC-regulated research reactors in the United States, see "Radioactive Road Trip," "PrimeTime Live," *ABC News*, 13 October 2005.

[97] See, for example, Philip Robinson, "Global Research Reactor Security Program," in *RERTR 2005: 27th International Meeting on Reduced Enrichment for Research and Test Reactors, Boston, Mass., 6-10 November* (Argonne, Ill.: Argonne National Laboratory, 2005).

[98] Interview with IAEA research reactor expert, September 2002. Thieves stealing material emitting 100 rem/hr might only receive 20 rem during the course of the theft, even if they picked up the material in their bare hands and carried it to a waiting truck. This would not even be enough to make them feel ill, let alone kill them—though it would modestly increase their long-term cancer risk. See J.J. Koelling and E.W. Barts, *Special Nuclear Material Self-Protection Criteria Investigation: Phases I and II*, vol. LA-9213-MS, NUREG/CR-2492 (Washing-

be a significant number of sites with irradiated HEU fuel that is not self-protecting by the IAEA standard and which therefore require significant upgrades to meet the IAEA recommendations.

Rate of progress. The current and planned rate of progress in upgrading HEU-fueled research reactors to meet the IAEA recommendations is fairly rapid, despite very modest budgets allocated to this effort. DOE reports that such upgrades were completed at only one site in FY 2006, but had been finished at five more sites by mid-2007. The last reactors slated for upgrades under current plans are to be completed in FY 2008 and FY 2009.[99]

Sustainability. DOE typically provides support for fixing and replacing systems it pays to install for a limited period. But in most cases there has not been an effort to work with these sites to ensure that effective security will be sustained after that limited period that is comparable to the approach that has been taken in Russia, and few budget resources are available for this purpose. At some of the sites, some important U.S.-supplied equipment is no longer working.[100] To date, it appears that only limited efforts have been made to work with countries where these facilities exist to ensure that effectively enforced regulations are put in place that would require that high levels of nuclear security were maintained in the future.

Securing Metric 4: Global Operating HEU Reactor Sites Upgraded to Meet Plausible Threats

Putting in place the modest measures called for in the IAEA physical protection recommendations is only the first step in providing effective security for these sites. Ultimately, every nuclear warhead and every significant cache of separated plutonium or HEU worldwide should have a security system able to defeat the plausible threats (both insider and outsider) in the country and region where it exists—that is, the security measures in place should be extensive enough so that the overall risk of nuclear theft from that cache is very low. Far less progress has been made in achieving this more demanding objective. But assessing that progress more specifically is difficult, as it requires judgments that compare the specific security measures that have been put in place to the threats outsider and insider adversaries might pose in different countries and regions, while keeping in mind the quantity and quality of nuclear material at these sites—and publicly available data on all of these points are sparse, at best. Thus, the estimates below should be understood as quite uncertain, intended to be illustrative, not definitive.

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ton, D.C.: U.S. Nuclear Regulatory Commission, 1982; available at http://www.sciencemadness.org/lanl1_a/lib-www/la-pubs/00307470.pdf as of 25 July 2007). Recently, analysts at Oak Ridge National Laboratory have concluded that for the doses thieves receive during a theft to be enough to disable them and prevent them from carrying out the theft, the dose rate would have to be roughly 100 times higher. See C.W. Coates et al., "Radiation Effects on Personnel Performance Capability and a Summary of Dose Levels for Spent Research Reactor Fuels," in *Proceedings of the 47th Annual Meeting of the Institute for Nuclear Materials Management, Nashville, Tenn., 16-20 July* (Northbrook, Ill.: INMM, 2006).

[99] Data provided by DOE, March 2007 and August 2007. Since these upgrades are not part of the Bratislava nuclear security plan, there is no requirement that they be completed by the end of 2008.

[100] At one site in a former Soviet state outside of Russia, to take just one example, an old reel-to-reel tape system installed with U.S. assistance years ago, intended to record information from the site's intrusion detection systems, continues to turn, but the tape heads have long since worn away, so nothing is recorded. Interview with U.S. laboratory expert, January 2007.

Table 2.2:
Global HEU-Fueled Research Reactors Upgraded to Meet Plausible Threats

Category	Total	Needed Upgrades	Upgraded to IAEA Recs	Still to be Upgraded
Russia Civil	52	52	12	40
Russia Military	12	12	5	7
Non-Russian FSU	8	8	2	6
Non-Russian FSU other sites	5	5	2	3
U.S. NRC-Regulated	8	8	0	8
U.S. DOE+DOD	11	0	0	0
Other Military	5	1	0	1
Other Civilian	43	27	0	27
Other Upgraded HEU Sites	3	3	0	3
Total	**147**	**116**	**21**	**95**
Percent of Needed Upgrades			*20*	*80*

Source: Author's estimates, based on data from Ole Reistad, personal communication, June 2007.

HEU-fueled research reactors in Russia. In the case of the Russian HEU-fueled research reactors, it can be assumed that all (or nearly all) of the civilian facilities have had comprehensive U.S.-sponsored upgrades completed.[101] Nevertheless, most civilian sites in Russia, like most civilian sites elsewhere in the world, would have great difficulty defending against a Beslan-scale attack (more than 30 well-trained attackers with automatic weapons, rocket-propelled grenades, and explosives, striking without warning). The upgrades being installed, and the kinds of forces guarding these sites, are not intended to provide protection against attacks at that scale—but attacks at that scale have happened repeatedly in Russia, without the security services providing warning. Similarly, it is unlikely that the upgraded security measures now in place could stop a theft by multiple insiders conspiring together—a type of incident that has occurred repeatedly at guarded non-nuclear facilities in Russia. Arguably, then, the only civilian HEU-fueled research reactors that have security strong enough to reduce the nuclear theft risk to a low level are those few that have both (a) upgraded security and (b) only very small amounts of HEU on-site, a category that may include something in the range of 10-15 of the 52 HEU-fueled civilian research reactors in Russia.

As noted earlier, it appears that most of Russia's military HEU-fueled research reactors are in closed nuclear cities. With fenced and guarded facilities within fenced closed cities, their protection against overt armed attack by outsiders is probably sufficient. And with the Federal Security Service (known by its Russian acronym FSB), the successor to the KGB, keeping a close eye on the staff at such sites, the protections against insider theft are likely to be somewhat better than those at civilian sites. But insider theft remains a serious concern, and these military-purpose reactors tend to have large quantities of very high-quality nuclear material. Those facilities where comprehensive security upgrades have not yet been completed pose particular concerns. As of the end of FY 2006, comprehen-

[101] As of the end of FY 2006, all but three of 50 buildings with civilian weapons-usable nuclear material in Russia had received U.S.-sponsored security upgrades. See U.S. Congress, *Nuclear Nonproliferation: Progress Made in Improving Security at Russian Nuclear Sites, but the Long-Term Sustainability of U.S.-Funded Security Upgrades Is Uncertain*, p. 14. For the purposes of this report, I assume that none of the three remaining buildings contain operational HEU-fueled research reactors.

sive upgrades were not yet completed for more than half of the buildings with weapons-usable nuclear material in the Rosatom weapons complex where DOE plans to perform upgrades;[102] the same may be true for a similar fraction of the HEU-fueled reactors within the Rosatom weapons complex. For the purposes of this report, I will count just under half of the military-purpose reactors—roughly the same proportion as the buildings in the weapons complex where comprehensive upgrades have been completed—as having been upgraded to a level of security that reduces the risk of nuclear theft to a low level.

HEU-fueled research reactors in the United States. DOE has substantially beefed up security measures for its sites with HEU and separated plutonium since the 9/11 attacks (though some planned upgrades will not be completed for some years to come); while less information is publicly available about DOD's approaches, it can be assumed that security at DOD HEU-fueled reactors has been upgraded to a comparable degree. By comparison to the terrorist and criminal threats that exist in many other countries, however, the ability of either outsider terrorist attackers or conspiracies of insiders to operate undetected in the United States are comparatively modest, and a case can be made that the risk of nuclear theft from these facilities was already fairly low before these upgrades were carried out; they are counted here as not having required upgrades. (As noted earlier, if one sets the bar for requiring upgrades at the level of security now required at DOE, the vast majority of the nuclear sites in the world would require security upgrades, and the needed upgrades would be extensive and expensive.) None of the U.S. NRC-regulated HEU-fueled research reactors should be considered adequately secured against plausible terrorist and criminal threats (though several have either very modest amounts of HEU on-site, or HEU that is quite radioactive).

HEU-fueled research reactors outside the United States and Russia. The upgrades implemented at HEU sites in the non-Russian states of the former Soviet Union were designed to meet the IAEA recommendations, and to be able to defeat a very minimal DBT. It is unlikely that these sites would be able to protect against outside attacks of the magnitude terrorists have demonstrated they can accomplish, or insider theft attempts involving more than one insider. Several of the upgraded sites, however, have had enough of their nuclear material removed (or had small enough amounts already) that the remaining material, if any, poses only a modest risk, even if the upgrades could not defeat very substantial threats. This appears to be true of Aqtau and Ulba in Kazakhstan, and the Photon facility and the Institute of Nuclear Physics in Uzbekistan. (Uzbekistan in particular represents

[102] At the time DOE provided data for the recent GAO report, DOE estimated that 210 buildings with weapons-usable nuclear material would be upgraded under the post-Bratislava plan, of which 124 were in the Rosatom weapons complex. U.S. Congress, *Nuclear Nonproliferation: Progress Made in Improving Security at Russian Nuclear Sites, but the Long-Term Sustainability of U.S.-Funded Security Upgrades Is Uncertain*, p. 14. More recently, DOE has increased its estimate of the number of buildings to be upgraded to 215; the extra five buildings are likely also to be in the Rosatom weapons complex. (Data provided by DOE, March 2007.) As of the end of FY 2006, 92 of these buildings had at least rapid upgrades installed. U.S. Congress, *Nuclear Nonproliferation: Progress Made in Improving Security at Russian Nuclear Sites, but the Long-Term Sustainability of U.S.-Funded Security Upgrades Is Uncertain*, p. 14. At that time, however, there were 39 buildings where rapid upgrades but not comprehensive upgrades had been completed (data provided by DOE, March 2007), of which nearly all were likely in the Rosatom complex. Hence it appears that 53-57 of the roughly 129 buildings slated for upgrades in the Rosatom weapons complex had not yet had comprehensive upgrades completed by the end of FY2006.

a major victory for threat reduction efforts: when the amount of HEU there was large, it represented an immense risk, located as it was in a country with an armed Islamic movement closely tied to al Qaeda, considerable domestic unrest, and massive corruption; by removing all the HEU there except a modest amount remaining in two reactor cores, GTRI has succeeded in reducing this risk to a low level.)

Similarly, the eight HEU sites outside the former Soviet Union that have received U.S.-sponsored upgrades got upgrades that met the IAEA recommendations; DOE did have a modest DBT in mind in implementing these upgrades, but they were not designed to be sufficient to meet substantial outsider and insider threats.[103] (GTRI is now focusing on a somewhat larger "default" DBT for these upgrades—default meaning that it might be increased or decreased in particular cases, if the threats in a particular country are judged to be unusually high or low—which may require augmenting the security systems at some of the sites already completed. The new "default" DBT is still modest, though it is comparable to what the NRC requires large HEU sites it regulates to be prepared to defend against.)[104]

Most civilian research reactors outside the United States and the former Soviet Union have only modest security measures in place. At one research reactor in a developed country which I recently visited, for example, the facility had retained a significant quantity of separated plutonium on-site even though there had not been funds to do any experiments with it for years; the cost of meeting that country's security rules for a Category I facility (the highest level of security, required for this amount of plutonium) was apparently so low that it was not worth the trouble to move this plutonium into another building on the same site which already contained large quantities of plutonium. Some of these reactors, however, have only very small amounts of HEU, and in these cases, the security measures already in place, modest though they are, may well be sufficient to keep the overall nuclear theft risk low. (The similar Slowpoke and Miniature Neutron Source Reactors (MNSRs), for example, each have lifetime cores containing less than a kilogram of HEU.)

Moreover, in some countries, such as Japan and Canada, terrorist and criminal threats appear to be less severe than in other countries. Every country in the world, however, faces some significant possibility for terrorists to strike or criminals to steal; Japan, after all, was the home of the Aum Shinrikyo terror cult, which launched the nerve gas attack in the Tokyo subways and also sought nuclear weapons.

As a rough estimate, I assume that the 13 Slowpoke or MNSR reactors and 10% of the remaining civilian HEU-fueled research reactors outside the United States and the former Soviet Union have such modest stocks of HEU that they pose little risk of nuclear theft even with the modest security measures in place, and hence do not require further upgrades. Given the modest security standards that U.S.-sponsored upgrade programs outside the former Soviet Union have so far been designed to meet, however, I will assume that no facilities outside the Soviet Union that still have substantial stocks of HEU have received upgrades adequate to defeat demonstrated terrorist and criminal threats.

[103] Interviews with DOE officials, July 2007.

[104] Interviews with DOE officials, July 2007.

Little information is publicly available about security for the small number of military-purpose research reactors in other countries, but given the roles of these reactors, in most cases substantial security measures are likely to be in place. Here, I estimate that only one of these reactors requires additional upgrades to meet demonstrated terrorist and criminal threats.

The global picture. All told, it appears that some 15-25 operational HEU-fueled reactors or related facilities around the world have received upgrades in recent years that are sufficient to protect against demonstrated threats, just under 20% of the HEU-fueled reactors that required upgrades to reduce the risk of nuclear theft. See Table 2.2.

Rate of progress. The new default DBT the GTRI program is seeking to implement in its future upgrades is likely to significantly reduce the risks of nuclear theft, if the hoped-for level of security can be achieved and sustained. This new target is likely to be sufficient to reduce the risk of nuclear theft to a low level for those sites with HEU stocks that are modest in size and quality. But sites with larger, higher-quality stocks would still pose dangerous (though reduced) risks, as these sites would still not be able to defend against the larger, more capable threats that terrorists and criminals have shown they are capable of. As upgrades proceed at the sites with more modest stocks, these sites will be added to the list of facilities whose security has been upgraded adequately to reduce the risk of theft to a low level. Similarly, some of the ongoing upgrades in Russia may bring HEU-fueled research reactors in the closed nuclear cities to a level of security where the remaining risk of nuclear theft is quite low. Moreover, in some cases HEU removal efforts reduce the quantity of HEU at some sites to a level low enough that the remaining risk of nuclear theft is low (even with fairly modest security measures in place), on the road to eliminating the HEU at those sites entirely.

Sustainability. Upgrades to levels of security beyond the IAEA recommendations are only likely to be sustained if policymakers and nuclear managers in those countries are convinced that the threat of nuclear theft and terrorism is a real and urgent threat to them, deserving the resources necessary to maintain high levels of security. Moreover, such security levels are only likely to be sustained once effectively-enforced regulations requiring them have been put in place. In most countries, neither this perception of the threat nor the required regulations are yet in place. Ultimately, the most sustainable solution is to remove the HEU from these sites entirely, converting these reactors to use LEU or shutting down reactors that are no longer needed.

Securing Metric 5: Global HEU-Fueled Research Reactors With All HEU Removed

Improved security measures can only reduce the risk of nuclear theft, never eliminate it. The only way to guarantee that nuclear material will not be stolen from a particular building is to remove the material, so there is nothing left to steal.

Data on how many bunkers and buildings have been cleared of nuclear weapons or weapons-usable nuclear materials worldwide over the last fifteen years is not publicly available. As one indicator, at least rough estimates of the number of HEU-fueled research reactors worldwide that have had all their HEU removed since U.S. efforts to take back such fuel were restarted in 1996 can be derived from publicly available data. The number of research reactors with and without all HEU

removed is quite different, in some cases, from the number of *sites,* because some sites may have more than one such reactor. Four critical assemblies, for example, were recently moved from the TA-18 site at Los Alamos to the Device Assembly Facility (DAF) in Nevada, and several other critical assemblies had existed at the TA-18 site in the past.

The first question is how big the job was to start with. One cannot use the number of reactors still operating with HEU as of 2007 as the baseline, for a reactor that has had all of its HEU removed, by definition, is no longer an operating HEU-fueled reactor. As a very rough estimate, it appears that the number of HEU-fueled reactors that were operating in 1996 (or had discharged their last HEU in the previous few years) was roughly 50% larger than it is today, in the range of 180-220 facilities.[105] All told, as of the early 1990s there were significant stocks of U.S.-origin HEU in some 34 countries,[106] and Soviet-origin HEU in 18 countries;[107] with one country (Romania) receiving HEU from both sources, and counting the United States and Russia themselves, this represents a total of some 53 countries that had civil HEU. (At that time, it appears that the countries that had research reactor HEU from other sources also had HEU from either the United States or the Soviet Union.)

How much of the job of removing HEU from that total set of facilities is done? Eleven countries have sent back all of their U.S.-origin HEU eligible for return to the United States, and 11 more have returned a portion of their U.S.-origin HEU.[108] At least two Soviet-supplied countries (Georgia and Iraq) have been cleared of all of their HEU.[109] All told, the available

[105] Author's estimates, based on historical research reactor data in Reistad, Maerli, and Hustveit, *Minimizing HEU-Fuelled Non-Explosive Applications*.. A similar baseline can be reached by another route: a DOE study in 2003 concluded that there were 128 research reactors or associated facilities around the world with 20 kilograms or more of HEU on-site. (See U.S. Congress, Government Accountability Office, *Nuclear Nonproliferation: DOE Needs to Take Action to Further Reduce the Use of Weapons-Usable Uranium in Civilian Research Reactors*, GAO-04-807 (Washington, D.C.: GAO, 2004; available at http://www.gao.gov/new.items/d04807.pdf as of 10 July 2007), p. 28.) If one adds to the 128 figure an estimate of the substantial number of facilities that had smaller amounts of HEU; adds the facilities that had already had their HEU removed by the time of the DOE study in 2003; and subtracts the "associated facilities"—HEU fuel fabrication sites and the like—one arrives at a similar estimate of the overall size of the problem when these efforts began.

[106] For a listing of these countries and which had sent back all or part of their HEU as of late 2003, see, for example, U.S. Congress, Government Accountability Office, *Nuclear Nonproliferation: DOE Needs to Consider Options to Accelerate the Return of Weapons-Usable Uranium from Other Countries to the United States and Russia*, GAO-05-57 (Washington, D.C.: GAO, 2004; available at http://www.gao.gov/new.items/d0557.pdf as of 10 July 2007), p. 9.

[107] This includes Belarus, Bulgaria, China (which apparently no longer has Soviet-supplied HEU), the Czech Republic, Georgia, Germany, Hungary, Iraq, Latvia, Kazakhstan, North Korea, Libya, Poland, Romania, Serbia, Ukraine, Uzbekistan, and Vietnam.

[108] See U.S. Congress, *DOE Needs to Consider Options to Accelerate the Return of Weapons-Usable Uranium*, p. 9. Since the data for that GAO report was compiled, DOE has succeeded in removing all the eligible U.S.-origin HEU from one additional country (Greece) but has identified additional eligible U.S.-origin HEU in Switzerland, so the total of countries with all eligible U.S.-origin HEU removed remains at eleven. (Data provided by DOE, June 2007.) Most of these countries no longer have any HEU at all, but a few still have either U.S.-origin HEU not eligible for the take-back effort, or HEU from other sources, so the number of U.S.-supplied countries with *all* HEU removed is smaller.

[109] The HEU once present at a nuclear institute in the breakaway Georgian region of Abkhazia has been missing since the 1990s, and the HEU once present at an institute near Tbilisi was removed in Operation Auburn Endeavor in 1998. See Philipp C. Bleek, *Global Cleanout: An Emerging Approach to the Civil Nuclear Material Threat* (Cambridge, Mass.: Project on Managing the Atom, Harvard University, 2004; available at http://bcsia.ksg.harvard.edu/BC-

data suggests that since the mid-1990s, U.S.-funded programs have contributed to the removal of all HEU from roughly 40-45 of the HEU-fueled research reactors worldwide, representing 20-25% of the estimated total.[110] This includes not only reactors whose HEU was removed as part of the various programs now included in GTRI, but also U.S. reactors whose HEU was removed, and the three critical assemblies at the Krylov Shipbuilding Institute in Russia, whose HEU was removed as part of the Material Consolidation and Conversion effort within the MPC&A program.[111] (It does not, however, include facilities where countries may have removed HEU with no help from the United States.) Several additional facilities have had all HEU removed except a small amount of material still in the reactor core, or material in the pool that has not yet cooled enough to ship.

Rate of progress. It appears that several facilities had all of their HEU removed during FY 2006. The pace is likely to accelerate over the next few years. Under GTRI's ambitious current plans, some 95% of the weapons-usable nuclear material it intends to remove would be removed by the end of 2010. Quite a number of facilities have converted to LEU in the last few years, or plan to do so in the next couple of years; much of the irradiated HEU at these sites is likely to be shipped out as soon as the material has cooled and money and equipment are available for the shipping. DOE hopes to complete shipments of the Soviet-supplied HEU that is slated to go back to Russia and has been discharged from reactors by the end of 2010. Some of the HEU in the former Soviet states, however is likely to be blended to LEU or disposed of in those states, an activity that will probably go beyond the 2010 deadline; in addition, HEU that is still being discharged from reactors will have to cool for a period before being shipped back, and some of that will be returned after 2010 also. For those reasons, DOE expects that it will continue to address an average of 60-90 kilograms of Soviet-supplied HEU each year from 2010-2013, and will remove the last Russian-origin HEU in 2015.[112] DOE also plans to finish the U.S. HEU return and its "emerging threats and gap materials" program in 2013 (though U.S.-origin LEU is expected to continue to return un-

SIA_content/documents/bleekglobalcleanout.pdf as of 09 July 2007); Thomas A. Shelton et al., "Multilateral Nonproliferation Cooperation: US - Led Effort to Remove HEU/LEU Fresh and Spent Fuel from the Republic of Georgia to Dounreay, Scotland (Auburn Endeavor/Project Olympus)," in *Proceedings of the 21st International Meeting on Reduced Enrichment for Research and Test Reactors (RERTR), Sao Paulo, Brazil, 18-23 October 1998* (Argonne, Ill.: Argonne National Laboratory, 1998; available at http://www.rertr.anl.gov/Fuels98/SpentFuel/SThomas.pdf as of 07 August 2007). Iraq's Soviet-supplied and French-supplied HEU was removed after the 1991 Gulf War.

[110] Author's estimate, based on the number of reactors cleaned out in the 11 countries that have returned all of their eligible HEU to the United States; an estimate of the number of reactors with all HEU removed in the 11 countries that have sent part of their eligible HEU fuel to the United States; an estimate of the number of HEU-fueled reactors in the United States itself that have had all their HEU removed since the mid-1990s; an estimate of the number of HEU-fueled reactors in Russia whose HEU has been removed partly as a result of U.S.-sponsored efforts; and an estimate of the number of Soviet-supplied HEU-fueled facilities which have had all their HEU removed and returned to Russia. Although the U.S. offer to take back HEU fuel that it had supplied (along with LEU under certain circumstances) was renewed in 1996, and I am using that year as the baseline in most cases, to be complete (and generous) I am including removals from some sites that took place somewhat earlier, such as the UN-sponsored removals of Iraq's HEU research reactor fuel after the 1991 Gulf War, or the removal of HEU from the Ulba facility in Kazakhstan in "Project Sapphire" in 1994.

[111] V.P. Struyev, Krylov Shipbuilding Institute, presentation at the 48th Annual Meeting of the Institute for Nuclear Materials Management, Tucson, Arizona, 10 July 2007.

[112] Data provided by DOE, August 2007.

til 2019).[113] Insufficient data are publicly available to estimate how many research reactors or associated facilities will still have HEU on-site when these programs are completed. It is clear, however, that unless significant changes occur, large amounts of HEU will continue to exist in many countries.[114]

HEU removals in kilograms. DOE tracks the progress of its programs to remove nuclear material from sites around the world by how many kilograms of HEU have been removed, rather than how many sites or research reactors have been cleared of HEU. The number of kilograms shipped is not as accurate an indicator of the fraction of the threat that has been reduced, because if a site had 500 kilograms of HEU and 100 kilograms were shipped away, there would be little or no reduction in the nuclear theft risk at that site. Nevertheless, this is the measure of progress in nuclear material removal for which the most detailed official information is publicly available.

DOE's GTRI program estimates that the universe of materials from which it will select materials to attempt to remove includes 18.7 tons of HEU and separated plutonium.[115] This total includes: all of the estimated 2.2 tons of Russian-origin HEU outside of Russia (all of which GTRI plans to remove);[116] all of the roughly 15.9 tons of U.S.-origin HEU outside of the United States (including an estimated 3.6 tons which meet the criteria for eligibility for the U.S. take-back program and 12.3 tons that do not); and 600 kilograms of other stocks of HEU and separated plutonium that have been identified as potentially vulnerable (all of which GTRI plans to remove).[117]

[113] Data provided by DOE, March 2007.

[114] See, for example, the projections of HEU stockpiles in 2020 in David Albright and Kimberly Kramer, "Civil HEU Watch: Tracking Inventories of Civil Highly Enriched Uranium," in *Global Stocks of Nuclear Explosive Materials* (Washington, D.C.: Institute for Science and International Security, 2005; available at http://www.isis-online.org/global_stocks/end2003/civil_heu_watch2005.pdf as of 25 July 2007).

[115] Data provided by DOE, July 2007. These DOE estimates are evolving as additional materials and additional pathways to address them are identified, and estimates are placed on a more consistent basis. In January 2007, for example, DOE estimated that the total universe of material was 22.8 tons. See U.S. Department of Energy, *Strategic Plan*, pp. 9-10. One important source of the change is a change in accounting. DOE has long counted the amount of HEU returned to the United States on the basis of the amount of HEU those fuel elements still contain, after some of it has been fissioned during irradiation. (In many research reactors, typical burnups reach 40-50% of the contained U-235, so the quantity of 90% enriched HEU might be reduced by 45% during irradiation.) But in the January data, the estimated total amount of U.S.-origin HEU eligible for return was based on the amount before irradiation, making the figure not directly comparable with the amount of material returned. In addition, certain stocks were accidentally double-counted, and that error has been corrected in the more recent estimates. (Discussions with DOE officials, July 2007.) At the same time, the quantity of materials the "gap" program plans to address continues to increase, as additional materials potentially available for removal are identified.

[116] According to data provided by DOE in June 2007, this estimated total currently amounts to 2,245 kilograms, up from an estimate of 2,154 in January 2007. See U.S. Department of Energy, *Strategic Plan*, p. 10. This estimate of the total does not include the material removed from Kazakhstan in Project Sapphire in 1994, or the large amount of low-assay HEU the Nuclear Threat Initiative paid to have moved from the former fast-neutron reactor at Aqtau and blended to LEU at the Ulba facility.

[117] Data provided by DOE, July 2007. When the Foreign Research Reactor Fuel Return program was renewed in 1996, it was estimated that there were 17.5 tons of U.S.-origin HEU abroad, of which 5.2 tons was eligible for the take-back offer. The smaller figures here result from taking into account the reductions in the amount of HEU resulting from part of it being fissioned during irradiation. In making the estimate of 3.6 tons of eligible HEU, DOE has assumed that the eligible material, consisting primarily of Materials Test Reactor (MTR) and Training, Research, Isotopes—General Atomics (TRIGA) reactor fuels, was irradiated to an average

There are substantial uncertainties in these estimates. Remarkably, DOE simply does not know how much U.S.-origin HEU exists in foreign countries, as current estimates: (a) are based on the amounts that were *licensed* for export, while the amounts actually exported may have been smaller in some cases; (b) are based, for a large portion of the total, on the amount of uranium originally shipped, not the amount of uranium that still exists after some of it has been fissioned during irradiation;[118] and (c) do not take into account that a portion of the material exported has been or will be reprocessed and recovered as LEU, after which it no longer exists as HEU. When nuclear material is exported to the countries of Euratom in particular, they are free to ship it from place to place within Euratom and to reprocess it, and have no obligation to inform the United States, leading to major uncertainties in tracking this material. DOE's total estimate includes 15.9 tons of U.S.-origin material; unclassified country-by-country estimates of HEU stocks, when combined with other information, suggest that the total amount of U.S.-origin HEU abroad may instead be in the range of 7-13 tons.[119] Congress should consider instructing DOE to work with other countries to prepare a detailed estimate of the amount of U.S.-origin and other civilian HEU that exists in each country worldwide, and its current status.

GTRI's estimated total of 18.7 tons of material potentially subject to removal is less than 1% of the roughly 2,300 tons of separated plutonium and HEU that exist in the world. As described in Chapter 1, even the civilian stockpiles of these materials come to some 250 tons of separated plutonium and 65 tons of HEU. GTRI's total is so small because it excludes (a) all of the plutonium and HEU in Russia, where the world's largest stockpiles exist (a separate DOE program, the Material Consolidation and Conversion [MCC] initiative part of the International Nuclear Material Protection and Cooperation program, has the job of helping Russia consolidate its civilian HEU in fewer locations); (b) all of the plutonium and HEU in the United States, home of the world's second largest stockpiles; (c) all military HEU and plutonium stockpiles in other countries; and (d) all civilian separated plutonium except for a few small stocks at sites thought to be vulnerable. On the other hand, GTRI's total estimate includes all U.S. and Russian-origin HEU abroad, along with hundreds of kilograms of other HEU and separated plutonium; since the United States and Russia provided more than 90% of the world's research reactor HEU, it appears that the estimate includes all or nearly all of the HEU at research reactors outside of the United States and Russia.

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burnup of 50% of U-235. Data provided by DOE, July 2007.

[118] As described in the previous note, DOE has modified its estimates for the HEU eligible for the return program to include this effect of irradiation; it has not similarly modified the estimate of 12.3 tons of non-eligible U.S.-origin HEU, however, because this material is in such a variety of forms that

[119] David Albright and Kimberley Kramer have estimated that 7.4-9.3 tons of U.S.-origin HEU exist in non-nuclear weapon states (based on amounts of original HEU, not the amounts that still exist after irradiation). See Albright and Kramer, "Civil HEU Watch." This leaves the United Kingdom and France, which had 1.8 tons and 4.1 tons of U.S.-origin HEU as of the early 1990s. For a high estimate of the total, I assume that: (a) none of the French HEU has been reprocessed; (b) all of the 1.5 tons of HEU still in the United Kingdom as of late 2003, as reported by Albright and Kramer, was U.S.-origin; and (c) that on average, only 10% of the summed total has been destroyed by irradiation, leading to a total of 13.4 tons of U.S.-origin HEU abroad. For a low estimate of the total, I assume that (a) both Britain and France have reprocessed one-third of their U.S.-origin HEU; (b) 30% of the summed total has been destroyed by irradiation; and (c) one ton of HEU was in the research reactor fuel reprocessed at La Hague in 2005-2006, leading to a total just under 7 tons of U.S.-origin HEU abroad.

GTRI plans to remove just under 5 tons of HEU and separated plutonium in its removal programs, roughly a quarter of its estimated universe of material.[120] This is a significant increase from the 4.4 tons GTRI planned to remove as of January 2007;[121] since that earlier estimate, DOE has identified additional opportunities to remove hundreds of kilograms of material.

GTRI argues that it is acceptable to leave some three-quarters of the material it has identified where it is, as this material "is considered to be secure or [has an] acceptable disposition path" being implemented or planned.[122] These judgments are not, however, based on any site-by-site examination of the actual state of security for these materials, or of the disposition plans for them. In essence, GTRI has decided to focus its resources on removing: (a) all of the HEU from Russian-supplied sites outside of Russia, all of which it considers vulnerable; (b) non-Russian, non-U.S. HEU and separated plutonium from other sites it considers vulnerable (in what it calls the "gap material and emerging threats" program); (c) a small remaining amount of eligible U.S.-origin HEU from low-income countries where it may be vulnerable; and (d) U.S.-origin HEU in high-income countries (eligible or not eligible) when those countries are willing to get rid of it and to pay the costs of doing so. When high-income countries are not interested in paying the costs of participating in the take-back program or otherwise reducing their stockpiles, their material will stay where it is, under current plans This reflects an implicit assumption that the remaining material in wealthy countries—the location of the vast majority of the HEU outside of the United States and Russia—is already secure enough. Indeed, DOE appears to be making only modest efforts to convince wealthy countries to send back or otherwise eliminate a larger fraction of their HEU.

The assumption of adequate security in wealthy countries is not always correct: as noted earlier, for example, the HEU-fueled research reactors in the United States itself that are regulated by the NRC have very weak security measures that do not fully meet IAEA recommendations. In Japan, to take another example, until the 9/11 attacks there were no armed guards at nuclear facilities—even if these facilities contained large quantities of HEU or separated plutonium.[123] (Now there are lightly armed members of the national police patrolling—but they are not required by Japanese regulations, and may someday be removed.) Until the entry into force of a new physical protection rule in late 2005, Japan did not require facilities with HEU or separated plutonium to have defenses able to defeat a specified DBT. Hence, for the six years between the 1999 revision of the IAEA's physical protection recommendations that called for such a DBT and the new law, Japan's facilities were arguably not in compliance with IAEA security recommendations. In short, decisions on removal priorities should be based on site-by-site assessments of theft risks, given the security levels, the plausible threats at that site, and the quantity and quality of the material present at that site, not on assumptions that material in wealthy countries poses little risk.

[120] Data provided by DOE, July 2007.

[121] See U.S. Department of Energy, *Strategic Plan*, pp. 9-10.

[122] U.S. Department of Energy, *Strategic Plan*, pp. 9-10.

[123] For a brief discussion of physical protection in Japan, with references, see Bunn and Wier, *Securing the Bomb 2006*, pp. 21-22. For an unclassified summary of the provisions of the new Japanese rules, see Shin Aoyama, "Current Nuclear Physical Protection Measures in Japan," paper presented at Seminar on Strengthening Nuclear Security in Asian Countries, Tokyo, 8-9 November 2006.

Nor is the argument that much of the uncovered material already has alternative disposition paths persuasive. Only a small proportion of HEU outside Russia and the United States has alternative disposition paths arranged. No country has yet decided on direct disposal of HEU research reactor fuel in geologic repositories. Only a few countries have contracted to have their research reactor fuel reprocessed. As of the end of 2006, only 2 tons of research reactor fuel (containing both HEU and LEU) had been reprocessed at the French reprocessing facility at La Hague (the only facility outside of Russia and the United States currently capable of processing this material), all of it from Belgium and Australia[124]—though long ago, some additional research reactor fuel had been reprocessed at the French Marcoule reprocessing plant and the British Dounreay reprocessing plant, both now closed. Irradiated research reactor fuel continues to build up all over the world.

GTRI's plan to take back only 1.3 tons of the eligible U.S.-origin HEU abroad is particularly surprising. This represents only one-third of DOE's estimate of the remaining quantity of eligible U.S.-origin HEU. When the take-back program was first announced, the expectation was that all or nearly all of the eligible material would be returned. By early 2004, the DOE Inspector General reported that DOE would probably only recover about half of the eligible material unless it took additional action to convince countries to send it back, and recommended that the effort be expanded to cover all U.S.-origin HEU abroad.[125] GTRI's current plan represents a major cutback in planned scope even from the status as of the Inspector General's report—the opposite of what the Inspector General recommended. This shift comes despite the fact that DOE nonproliferation experts told the Inspector General "that all of the HEU -- not just the portion covered by the Acceptance Program—represents a security concern to the United States."[126] The DOE Inspector General could find "no discernable rationale" for taking back some of the HEU in key countries and leaving the rest.[127] A similar 2004 GAO study called for accelerating the return of U.S.-origin HEU, and recommended that DOE consider offering new incentives for high-income countries to send back their HEU; DOE does not yet appear to have taken action to implement this suggestion.[128]

[124] See Philippe Bernard Estelle Hélaine, Jean-Luc Emin, Dominique Lepoittevin, Frédéric Gouyaud, "Research and Test Reactor Fuel Treatment at AREVA Nc La Hague," in *Proceedings of Research Reactor Fuel Management 2007, Lyon, France, 11-15 March* (Brussels: European Nuclear Society, 2007; available at http://www.euronuclear.org/meetings/rrfm2007/transactions/rrfm2007-transactions.pdf as of 12 July 2007). GTRI specifically mentions only Belgium, Canada, France, and the U.K. as countries where the "material is considered to be secure or [has an] acceptable disposition path." U.S. Department of Energy, *Strategic Plan*, p. 10. All told, these countries are thought to have received 7.8 tons of U.S.-origin HEU, leaving the reason for not addressing most of the remainder of the estimated 19.6 tons of U.S.-origin HEU abroad unexplained. Moreover, while France is likely to reprocess its research reactor fuel at La Hague, and Belgium has contracted to reprocess a portion of its research reactor fuel there, there is no obvious disposition path for HEU research reactor fuel in Canada or in the U.K. (now that the Dounreay reprocessing plant, which once handled research reactor fuel, has closed).

[125] U.S. Department of Energy, Office of the Inspector General, *Audit Report: Recovery of Highly Enriched Uranium Provided to Foreign Countries*, DOE/IG-0638 (Washington, D.C.: DOE OIG, 2004; available at http://www.ig.energy.gov/documents/CalendarYear2004/ig-0638.pdf as of 22 June 2007).

[126] U.S. Department of Energy, *Audit Report: Recovery of Highly Enriched Uranium Provided to Foreign Countries*, p. 2.

[127] U.S. Department of Energy, *Audit Report: Recovery of Highly Enriched Uranium Provided to Foreign Countries*, p. 2.

[128] U.S. Congress, *DOE Needs to Consider Options to Accelerate the Return of Weapons-Usable Uranium*.

GTRI divides its removal plans into three categories: the Russian Research Reactor Fuel Return (RRRFR) effort; the Foreign Research Reactor Spent Nuclear Fuel Acceptance (FRRSNF) program (which handles the U.S.-origin HEU eligible for the take-back program); and the "gap materials and emerging threats" program (which handles non-eligible U.S.-origin HEU and potentially vulnerable HEU and separated plutonium not covered by the other efforts). These efforts have different levels of maturity and are making progress at different rates. Figure 2.3 shows the materials removed in each of these programs each year, and GTRI's projections for the future.[129]

Russian-origin HEU. The RRRFR effort has dramatically increased the pace of removals of Soviet-supplied HEU since the founding of GTRI, from a typical record of one shipment every four years to several shipments per year. GTRI plans to remove all of the estimated 2.2 tons of Russian-origin HEU outside of Russia by the end of 2015.[130] The program plans to remove all of the HEU covered by the U.S.-Russian action plan resulting from the Bratislava summit by the end of 2010; the remaining material to be addressed by 2015 includes HEU that some Russian-supplied states want to blend outside of Russia (rather than sending it back to Russia), and material that will still be being irradiated or will not yet be cooled enough to ship by 2010. By the end of fiscal year 2006, this program had shipped 228 kilograms of Russian-origin HEU back to Russia, roughly 10% of the total DOE plans to remove in this effort.[131] Another 268 kilograms was removed in a single shipment from the Rossendorf site in Germany in December 2006, bringing the total by the end of calendar 2006 to 496 kilograms. Table 2.3 shows the shipments under this program to date. DOE plans to increase the pace to hundreds of kilograms per year through the end of 2010, and then return to 60-90 kilograms per year until 2013.[132]

Eligible U.S.-origin materials. Most of the HEU GTRI plans to return under the FRRSNF effort has already been returned. By the end of FY 2006, DOE estimates that the fuel assemblies returned to the United States included 1,056 kilograms of HEU.[133] This represents 85% of the 1,253 kilograms of HEU GTRI plans to return in this effort (though it is less than 10% of the of GTRI's estimate of the total U.S.-origin HEU worldwide). GTRI expects to be done with all but 14 kilograms of the total it plans to return by the end of FY 2009, and with the remainder by the end of 2013.[134] These returns have not accelerated substantially since the establishment of GTRI, and are not expected to do so in the future.

"Gap" nuclear materials. This is a new effort to address HEU and separated plu-

[129] Data provided by DOE, August 2007.

[130] Data provided by DOE, August 2007.

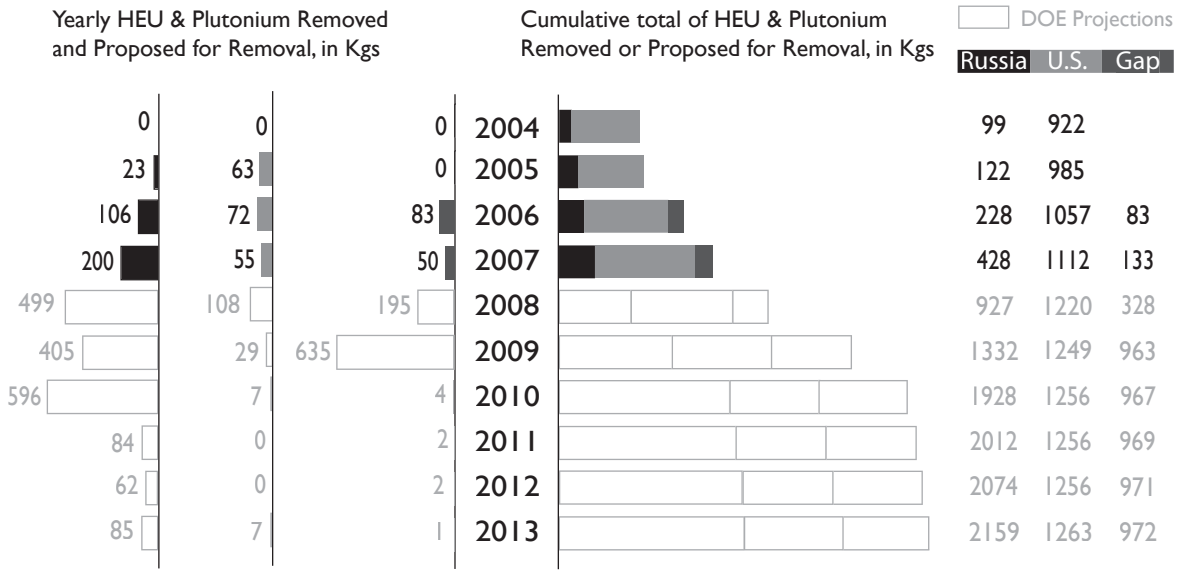
[131] This figure includes the 48 kilograms of HEU sent back to Russia from the Vinca Institute of Nuclear Sciences in Serbia, but does not include the 581 kilograms of fresh HEU shipped to the United States from the Ulba facility in Ust-Kamenogorsk, Kazakhstan, in Project Sapphire in 1994, or the roughly 5 kilograms of HEU shipped from Georgia to the United Kingdom in Project Auburn Endeavor in 1998. For discussions of these shipments, see, for example, Bleek, *Global Cleanout*. See also Chris Flores, "Project Sapphire: A Nuclear Odyssey: Defusing a Lethal Legacy," *News & Advance*, 29 December 2002; William C. Potter, "Project Sapphire: U.S.-Kazakhstani Cooperation for Nonproliferation," in *Dismantling the Cold War: U.S. And NIS Perspectives on the Nunn-Lugar Cooperative Threat Reduction Program*, ed. John M. Shields and William C. Potter (Cambridge, Mass.: MIT Press, 1997); Shelton et al., "Multilateral Nonproliferation Cooperation."

[132] Data provided by DOE, August 2007.

[133] Data provided by DOE, August 2007.

[134] Data provided by DOE, March 2007.

Figure 2.3:
Past and Projected U.S.- Assisted HEU Removals



Source: Data provided by DOE, August 2007.

tonium stockpiles not previously covered by any program, and it is just gathering steam. FY 2006 was the first year that this effort removed any material; during FY 2006, this program helped remove 83.4 kilograms of fresh HEU from facilities in Canada, Belgium, and the Netherlands; another 18.3 kilograms from Canada followed in February 2007, bringing the total by that time to 101.7 kilograms.[135] GTRI expects to accelerate this effort over the next few years, with hundreds of kilograms of material to be removed in FY 2009 in particular, and to finish it by the end of FY 2013.[136]

All told, these three programs removed 261 kilograms of HEU during FY 2006. While this represents a significant acceleration since GTRI was established, a further doubling of the average yearly pace would be needed to meet GTRI's goal of removing 4.9 tons of HEU by the end of 2013.

In addition to these three programs, there is the Material Consolidation and Conversion effort in Russia, which had removed 8.4 tons of HEU from Russian facilities and blended it to LEU by the end of FY2006, with a goal of removing and blending 17 tons by the end of 2015.[137] Finally, there is the HEU removed from research reactors within the United States, but information on that amount is not publicly available.

HEU reactor conversions and shutdowns. Before the HEU can be removed

[135] Data provided by DOE, June 2007 and September 2007. While these were not among the world's most vulnerable nuclear sites, such high-quality HEU poses some risk wherever it exists, and these countries were willing to return this material to the United States and pay much of the cost of doing so.

[136] Data provided by DOE, March 2007. At that time, the gap material program had identified 972 kilograms of material it planned to address; by June, this had increased to some 1400 kilograms of material. Further increases can be expected in the future as additional materials that can and should be removed are identified.

[137] U.S. Department of Energy, *FY 2008 NNSA Budget Request*, p. 474.

Table 2.3:
U.S. Assisted Removals of Russian-Origin Highly Enriched Uranium (HEU) Fuel

Location	Date	Material Removed
Ulba, Kazakhstan [Project Sapphire]	Nov 1994	581 kg HEU (fresh)
Tbilisi, Georgia [Auburn Endeavor]	Apr 1998	~5kg HEU (fresh)
Vinca Institute, Yugoslavia	Aug 2002	48 kg HEU (fresh)
Pitesti Institute, Romania	Sep 2003	14 kg HEU (fresh)
Sofia, Bulgaria	Dec 2003	~17 kg HEU (fresh)
Tajura, Libya	Mar 2004	16 kg HEU (fresh)
Institute of Nuclear Physics, Uzbekistan	Sep 2004	~3 kg HEU (fresh)
Rez, Czech Republic	Dec 2004	6 kg HEU (fresh)
Salaspils, Latvia	May 2005	~3 kg HEU (fresh)
Czech Technical University, Czech Republic	Sep 2005	14 kg HEU (fresh)
Institute of Nuclear Physics, Uzbekistan	Apr 2006	63 kg HEU (irradiated)
Tajura, Libya	July 2006	3 kg HEU (fresh)
MARIA, Institute for Atomic Energy, Poland	Aug 2006	40 kg HEU (fresh)
Rossendorf, Germany	Dec 2006	268 kg HEU (fresh)

Source: Matthew Bunn and Anthony Wier, *Securing the Bomb 2006* (Cambridge, MA: Project on Managing the Atom, Harvard University, and Nuclear Threat Initiative, July 2006), and data provided by DOE, August 2007.

from a research reactor, the reactor must either be converted to non-HEU fuel or shut down. Since its establishment, GTRI has accelerated and expanded the long-standing effort to convert research reactors to LEU fuel.

Several definitions of the total scope of conversion or shut-down work to be done are possible. Focusing on research reactors, as noted earlier, the latest data suggest that as of the end of 2006 there were roughly 140 research reactors operating with HEU fuel worldwide; by DOE's estimate, adding the reactors the program has already succeeded in converting brings the total scope of the problem to 192 HEU-fueled research reactors.[138] Other reactors, however, also use HEU fuel, and might be considered for conversion or shut-down: these include one commercial reactor (the BN-600 fast neutron reactor in Russia); at least five operating reactors for producing plutonium or tritium (all in Russia); fifteen reactors on nine nuclear icebreakers (all in Russia); scores of reactors for nuclear submarines and surface ships (primarily in Russia and the United States); and several reactors around the world that use some 50 kilograms of HEU per year for production of medical isotopes. Thus the total number of reactors currently using either HEU fuel or HEU targets, plus the reactors already converted to LEU, is over 250.

Until recently, GTRI sought to convert 106 HEU-fueled research reactors to use LEU fuel. By early 2007, however, GTRI had expanded its list of reactors targeted for conversion to 129; by DOE's count, that still left 63 operating HEU-fueled research reactors outside of GTRI's scope.[139] The 63 reactors not targeted for conversion represent over 40% of the roughly 140 research reactors still operating with HEU

[138] DOE has a total of 207 reactors on its current list; see U.S. Department of Energy, *Strategic Plan*, p. 7. Fifteen of the entries on this list, however, are on nine Russian nuclear icebreakers, so there are 192 research reactors on this list.

[139] U.S. Department of Energy, *Strategic Plan*, p. 7. GTRI lists a total of 78 reactors outside of the scope, but as with the total of 207, 15 of these are nuclear icebreakers.

worldwide today. Many of these reactors would be technically difficult or impossible to convert with either existing fuels or fuels likely to be available in the next 3-10 years.

GTRI estimates that from 1978 through the end of FY 2006, 46 HEU-fueled reactors converted to LEU fuel, and two that DOE had planned to help convert were instead shut down before converting.[140] The two reactors that shut down did so without DOE's help, and so should not be counted as successes of DOE's program, but they do reduce the list of targeted reactors from 129 to 127.[141] (Actually, over 100 HEU-fueled research reactors, not just the two DOE lists, have shut down since 1978, far more than have converted to LEU[142]—even though there was no formal program to give such reactors incentives to close. This reemphasizes that helping to convince reactors to shut down may be, in many cases, a faster and cheaper alternative to helping them to convert to LEU.) The 46 converted reactors represent over 35% of the 127 target, though less than a quarter of DOE's estimate of the total number of HEU-fueled research reactors.

As noted, conversion has accelerated since the establishment of GTRI: five conversions occurred in FY 2006 alone, and three more conversions and two more shut-downs had occurred by mid-2007.[143] DOE hopes to have 106 reactors converted by 2014, and to have all 129 converted or shut down by the end of FY 2018.[144] Meeting that goal would require sustaining an average pace of conversions and shut-downs somewhat higher than that achieved in 2006 throughout the remaining years of the effort. Achieving such a pace will be very challenging; it will require, in particular, new approaches to convincing reactor operators, particularly those who already have enough fuel for decades, to shift to LEU fuels.

It is also important to convert facilities that use HEU targets to produce medical isotopes. Approximately 95% of the molybdenum-99 (Mo-99) produced worldwide is made from HEU, and Mo-99 is by far the most commonly used isotope in diagnostic procedures.[145] Approximately 50 kilograms of HEU are irradiated for this purpose each year.[146] There are four large producers (including companies in Canada, the Netherlands, Belgium, and South Africa). Only MDS Nordion, in Canada, is continuing to receive regular supplies of HEU from the United States, while the others are continuing production with their existing stockpiles of HEU.[147] (Two

[140] Data provided by DOE, February 2007.

[141] Realistically, some of the 46 converted reactors are also difficult to count as successes of DOE's program. Iran's Tehran Research Reactor, for example, could not get U.S. fuel or conversion assistance after the 1979 revolution, and Argentina helped them to convert. Conceivably one might count this as an indirect success of the conversion program, since the program helped Argentina develop the technology which allowed this conversion (and other efforts, such as Argentina's export of a modern LEU research reactor to Australia).

[142] Reistad, Maerli, and Hustveit, *Minimizing HEU-Fuelled Non-Explosive Applications*..

[143] Data provided by DOE, August 2007.

[144] U.S. Department of Energy, *Strategic Plan*, p. 7.

[145] George F. Vandegrift, "Facts and Myths Concerning 99-Mo Production with HEU and LEU Targets," in *The 27th International Meeting on Reduced Enrichment for Research and Test Reactors, Boston, Mass., 6-10 November 2005* (Argonne, Ill.: Argonne National Laboratory, 2005; available at http://www.rertr.anl.gov/RERTR27/PDF/S8-1_VandeGrift.pdf as of 12 July 2007).

[146] George Vandegrift, Argonne National Laboratory, presentation at the 48th Annual Meeting of the Institute for Nuclear Materials Management, Tucson, Arizona, 10 July 2007.

[147] George Vandegrift, Argonne National Laboratory, presentation at the 48th Annual Meeting of the Institute for Nuclear Materials Management, Tucson, Arizona, 10 July 2007.

smaller producers, in Argentina and Australia, already produce Mo-99 with LEU targets, and Indonesia will convert its production in 2007.[148]) Isotope production accounts for a substantial fraction of the HEU the United States exports each year. DOE and international partners have been successful in developing options that would allow the major producers to convert to LEU. But the largest producers have so far resisted conversion, and successfully lobbied to weaken U.S. laws restricting export of HEU to facilities that were committed to convert when appropriate LEU targets became available.[149]

Summary: How Much Have U.S.-Funded Nuclear Security Programs Accomplished?

Figure 2.4 summarizes the estimates above of the progress of U.S.-funded programs to improve security for nuclear weapons and materials around the world. As can be seen, these programs have made real progress, demonstrably improving security for some of the world's highest-risk stockpiles. They have represented an excellent investment in the security of the United States and the world. But there is an enormous amount that remains to be done. A dangerous gap remains between the urgency of the threat and the scope and pace of the U.S. and international response.

[148] George Vandegrift, Argonne National Laboratory, presentation at the 48th Annual Meeting of the Institute for Nuclear Materials Management, Tucson, Arizona, 10 July 2007.

[149] For a pointed critique of the major producers' lobbying efforts on this issue, see Alan J. Kuperman, "Bomb-Grade Bazaar," *Bulletin of the Atomic Scientists* 62, no. 2 (March/April 2006), pp. 44-50.. For a good critique of the major producers' arguments that production with LEU would be prohibitively costly or generate too much waste, see Vandegrift, "Facts and Myths Concerning 99-Mo Production."

Improved Securing Metrics for the Future

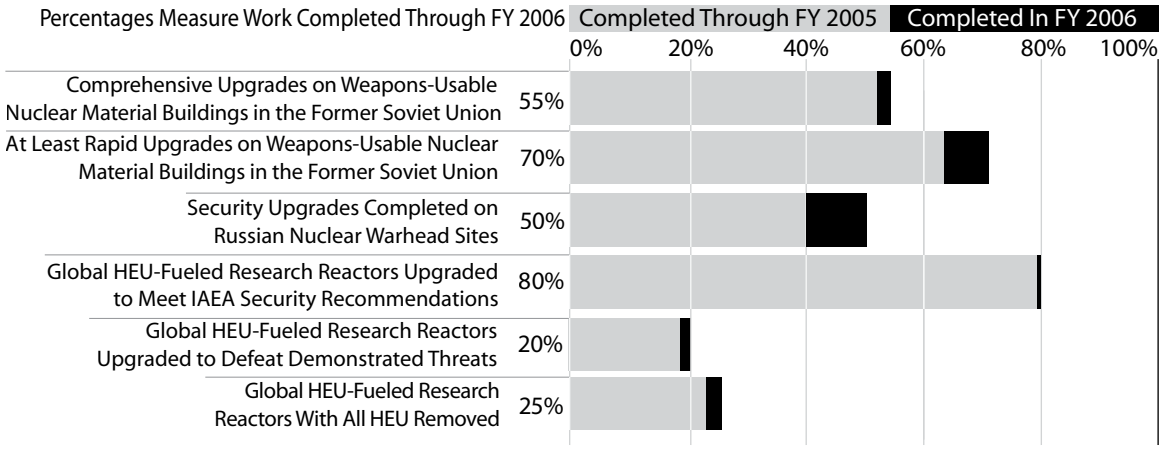
In essence, there are three goals that programs to improve nuclear security must achieve:

- Security must be improved fast enough, so that the improvements get there before thieves and terrorists do.
- Security must be raised to a high enough level, to make sure that the threats that terrorists and criminals have shown they can pose to such sites can be defeated.
- Security must be improved in a way that will last, including after foreign assistance phases out, so that these sites do not become vulnerable again in a few years' time.

There are clearly tensions among these three goals: putting in place security systems to defeat larger threats, and security systems that will stand the test of time, inevitably takes longer than slapping together less capable and long-lasting systems. Yet meeting all three goals is essential if the objective of keeping nuclear weapons and materials out of terrorist hands is to be met. Moreover, as discussed at the outset, progress toward many of the most important goals is very difficult to measure quantitatively. Ultimately, a balance of a variety of different measures will be needed to get a realistic picture of how much nuclear security is improving. There are a number of plausible metrics for assessing progress toward sustainable security over time.

The fraction of sites with nuclear security and accounting systems that are performing effectively. The best single such measure would be one that was performance-based: the fraction of the buildings containing

Figure 2.4:
Progress of U.S.-Funded Programs to Secure Nuclear Stockpiles



Source: Author's estimates.

warheads or nuclear material that had demonstrated, in realistic performance tests, the ability to defend against a specified threat. Unfortunately, for nuclear warheads and materials in the former Soviet Union, such data do not yet exist (and even less information of this kind is available for nuclear stockpiles in much of the rest of the world). Another indicator of effective performance—in those cases where nuclear regulatory authorities have set effective nuclear security rules and have put in place effective inspection approaches—would be the fraction of facilities that receive high nuclear security marks in regulatory inspections.[150] An even more ambitious approach would be to attempt to assess the overall risk of theft at each site, and then track whether these risks were increasing or decreasing, and by how much. In DOE's own complex, each facility is required to perform such estimates of overall risk, based on the security system's assessed ability to defeat a specified DBT and on the quantity and quality of nuclear material at the site. If recipient countries undertook similar approaches (possibly with U.S. assistance in doing so), it might be possible to collect at least partial data on whether these overall assessments of risk were increasing or decreasing, and how substantially. Yet another approach would be to assess, for each site, performance in a broad range of areas important to nuclear security and accounting, and then use some form of weighting (based on expert judgment) to provide an overall performance rating—and then track changes in the overall performance rating at different sites.[151]

The priority the recipient state's government assigns to nuclear security and accounting. This could be assessed by senior leadership attention and resources assigned to the effort, along with statements of priority, decisions to step up nuclear security requirements, and the like.

The presence and effective enforcement of stringent nuclear security and accounting regulations. The effectiveness of regulation of nuclear security and accounting could be judged by whether rules have been set which, if followed, would result in ef-

[150] DOE uses this metric to track the performance of its own nuclear security program. See U.S. Department of Energy, *Performance and Accountability Report: FY 2005* (Washington, D.C.: DOE, 2006; available at http://www.cfo.doe.gov/progliaison/2005pr.pdf as of 10 July 2007), p. 83.

[151] An approach of this kind was developed at Lawrence Livermore National Laboratory some years ago for use in the MPC&A program, but was never accepted for broad implementation.

fective nuclear security and accounting programs, and whether approaches have been developed and implemented that successfully convince facilities to abide by the rules to a degree sufficient to achieve that objective. Such an assessment would have to rely on expert judgment, rather than simply counting a specific number of regulations written, enforcement actions taken, and the like, as such measures of the *quantity* of regulatory action are usually almost unrelated to the actual *effectiveness* of regulation.[152] Surveys of managers and other personnel at nuclear sites about their experience with regulators and inspectors, and with enforcement and other approaches to encouraging compliance, could also be helpful in assessing the effectiveness of regulations.

The fraction of sites with long-term plans in place for sustaining their nuclear security and accounting systems, and resources budgeted to fulfill those plans. DOE has been contracting with facilities to develop cost estimates and plans for maintaining and operating their nuclear security and accounting systems. This metric would assess the fraction of sites that have completed such an estimate, and which appear to have a realistic plan for funding those costs once international assistance comes to an end. A simple metric along the same lines would be the total amount of money a particular country (or facility) is investing in nuclear security and accounting, compared with an assessment of overall needs. (Similar estimates could be made for personnel resources as well as financial resources.)

The presence of strong "security cultures." Effective organizational cultures are notoriously difficult to assess, but critically important. Ideally, nuclear security culture should be measured by actual day-in, day-out behavior—but developing effective indicators of day-to-day security performance has proven difficult. Potential measures of *attitudes* that presumably influence behavior include the fraction of security-critical personnel who believe there is a genuine threat of nuclear theft (both by outsiders and by insiders), the fraction who understand well what they have to do to achieve high levels of security, the fraction who believe that it is important that they and everyone else at their site act to achieve high levels of security, the fraction who understand the security rules well, and the fraction who believe it is important to follow the security rules. Such attitudes could be assessed through surveys, as is often done to assess safety culture—though enormous care has to be taken in designing the specifics of the approach, to avoid employees simply saying what they think they are supposed to say.[153]

The presence of an effective infrastructure of personnel, equipment, organizations, and incentives to sustain MPC&A. Each of these areas would likely have to be addressed by expert reviews, given the difficulty of quantification.

In 2001, DOE's MPC&A program took a first cut at the complex task of developing appropriate metrics to assess the real state

[152] Malcolm K. Sparrow, *The Regulatory Craft: Controlling Risks, Solving Problems, and Managing Compliance* (Washington, D.C.: Brookings Institution Press, 2000).

[153] For a brief discussion of such safety culture surveys, see International Atomic Energy Agency, *Safety Culture in Nuclear Installations: Guidance for Use in the Enhancement of Safety Culture*, IAEA-TECDOC-1329 (Vienna: IAEA, 2002; available at http://www-pub.iaea.org/MTCD/publications/PDF/te_1329_web.pdf as of 09 July 2007).

of progress toward achieving sustainable security at former Soviet sites.[154] The program is now putting a substantial focus on progress toward strong security cultures and long-term sustainability as part of developing a new strategic plan. But there is still more to be done to develop performance measures that adequately reflect the real state of progress, but are simple enough to be useful to policymakers.

[154] U.S. Department of Energy, *MPC&A Program Strategic Plan* (Washington, D.C.: DOE, 2001; available at http://www.nti.org/e_research/official_docs/doe/mpca2001.pdf as of 25 July 2007), pp. 26-28.

3 NEXT STEPS IN NUCLEAR SECURITY

Scores of sites where nuclear weapons or their essential ingredients exist, in countries all around the world, remain dangerously insecure. Each day that passes could be the one when enough material for a nuclear bomb gets stolen. Global efforts to secure these stockpiles must be strengthened and accelerated, to ensure that removal efforts or effective and sustainable security upgrades reach the vulnerable stockpiles before the thieves do. Today, there remains a dangerous gap between the urgency of the threat and the scope and pace of the U.S. and global response—creating unnecessary dangers that nuclear thieves will get bomb material to terrorists before they can be stopped. As the last chapter documented, existing programs have done a great deal to reduce this risk—but much more remains to be done to prevent a nuclear 9/11.

A Global Campaign to Prevent Nuclear Terrorism

President Bush, working with other world leaders, should launch a global campaign to lock down every nuclear weapon and every significant cache of potential nuclear bomb material worldwide, as rapidly as that can possibly be done—and to take other key steps to reduce the risk of nuclear terrorism. This effort must be at the center of U.S. national security policy and diplomacy—an issue to be raised with every country with stockpiles to secure or resources to help, at every level, at every opportunity, until the job is done.

This campaign should creatively and flexibly integrate a broad range of policy tools to achieve the objective—from technical experts cooperating to install improved security systems at particular sites to Presidents and Prime Ministers meeting to overcome obstacles to cooperation. In some cases, the recently launched Global Initiative to Combat Nuclear Terrorism may provide the right forum to pursue these goals; in others, high-level bilateral initiatives such as the nuclear security agreement reached between President Bush and Russian President Putin in 2005 may offer the most effective approach; in still others, cooperation led by international organizations such as the International Atomic Energy Agency (IAEA) may be the forum that other countries most readily accept.

This campaign should be driven by a genuinely prioritized plan, adapted as the effort proceeds, focusing on those sites and transport legs where there are the largest opportunities for reductions in risk. Every policy tool available should be used in an integrated way to achieve the overall objective of ensuring that every nuclear warhead and every significant cache of highly enriched uranium (HEU) and plutonium worldwide is secure enough so that the risk of nuclear theft and terrorism it poses is very low. Such an integrated approach would offer a far better chance of exploiting potential synergies and closing dangerous gaps than the current approach, in which each of these tools is being pursued largely independently, often by officials with little awareness of what efforts are ongoing on other tracks.

To succeed, this campaign should be based not just on donor-recipient relation-

ships but on real partnerships, integrating ideas and resources from countries where upgrades are taking place in ways that also serve their national interests. For countries like India and Pakistan, for example, the opportunity to join with the major nuclear states in the leadership of a joint global effort to solve a common problem is more politically appealing than portraying the work as U.S. assistance necessitated because they are unable to adequately control their nuclear stockpiles on their own. It is essential to pursue approaches that make it possible to cooperate in upgrading nuclear security without demanding that countries compromise their legitimate nuclear secrets—and the specific approaches should be crafted to each national culture, secrecy system, and set of circumstances.

Goals, Follow-Up, and Financing

President Bush should immediately begin working with leading nuclear weapons and nuclear energy states to convince them to participate in this campaign, and to agree to:

- Ensure that all stockpiles of nuclear weapons and weapons-usable materials under their control would be protected at least to a common security standard, sufficient to defeat the threats terrorists and criminals have demonstrated they can pose. (Participants would be free to protect their stockpiles to higher standards if they perceived a higher threat in their country.) For example, the commitment could be to provide protection at least against a modest group of well-armed and well-trained outsiders (capable of operating as more than one team), one to two well-placed insiders, or both outsiders and insiders working together.

- Work with other states to convince them to join the commitment to this common standard and help them (where necessary) to put the agreed level of security in place.

- Develop and put in place transparency measures that will help build international confidence that the agreed security measures have in fact been taken, without providing public information that would be helpful to terrorists.

- Sustain security levels meeting the agreed standard indefinitely, using their own resources, after any international assistance they may be receiving comes to an end.

- Reduce the number of locations where nuclear weapons and weapons-usable nuclear materials are located, achieving higher security at lower cost.

- Put in place border and transhipment controls that would be as effective as practicable in interdicting nuclear smuggling, as required by United Nations Security Council Resolution (UNSCR) 1540, and help other states around the world to do likewise.

- Drastically expand intelligence and law enforcement sharing related to indicators of nuclear theft risks; nuclear smuggling and criminal networks that might contribute to those risks; groups with ambitions to commit catastrophic terrorism; and other subjects related to preventing nuclear terrorism.

- Pass laws making actual or attempted theft of a nuclear weapon or weapons-usable nuclear material, unauthorized transfers of such items, or actual or attempted nuclear terrorism crimes comparable to treason or murder.

- Cooperate to strengthen nuclear emergency response capabilities—including nuclear materials search capabilities

that could be deployed rapidly anywhere in the world in response to an unfolding crisis.

- Exchange best practices in security and accounting for nuclear warheads and materials—to the extent practicable—as is already done in the case of nuclear safety.

- Strengthen the ability of the IAEA to contribute to preventing nuclear terrorism.

- Take such other actions as the parties agree are needed to reduce the risk of nuclear terrorism.

This campaign would be focused on taking concrete actions to reduce the risk of nuclear terrorism—and in particular, on ensuring that every nuclear weapon and every kilogram of nuclear material worldwide is secure and accounted for. The goal would be to accomplish that objective as quickly and effectively as possible. In particular, the participants should agree on a target of putting in place security measures sufficient to meet the agreed minimum standard for all stockpiles of nuclear weapons and weapons-usable materials worldwide within four years or less. In many cases, this would mean countries taking action to improve security for their own stockpiles, perhaps with a modest amount of international advice and exchange of best practices. In others, U.S. or other international funding or expertise might be critical to getting the job done effectively and quickly.

A strong mechanism for ensuring that the initial commitments were fulfilled would be an important element of such a global campaign. It may be that such a mechanism can be established as part of the Global Initiative to Combat Nuclear Terrorism, which already includes periodic reviews of progress on a joint action plan. Key participants in the nuclear security campaign should each designate senior officials to be responsible for all aspects of implementation, and these senior officials should meet regularly to develop agreed plans with measurable milestones, to oversee progress, and to develop means to overcome obstacles. This group should be a standing organization, meeting regularly until the participants agree that it is no longer needed. The group should report to the leaders of the participating states on a regular basis, perhaps once every six months. Such a mechanism would help to avoid the fate of past such global initiatives, which have sometimes been announced at summits with great fanfare and then went nowhere when the summit spotlight was gone.

The United States and other key participants in such a global campaign should commit to providing the resources necessary to ensure that lack of funding does not constrain the pace at which nuclear stockpiles around the world can be secured and consolidated. As the senior contact group develops more detailed plans, they should be tasked with estimating the costs of implementation, and participants should make pledges sufficient to complete the work at the fastest practicable pace.

Funds for implementing the actions agreed to in such a campaign could be drawn in part from funds pledged for an earlier initiative, the Global Partnership Against the Spread of Weapons and Materials of Mass Destruction announced at the G8 summit in Kananaskis, Canada, in 2002.[1] To date, unfortunately, the Global

[1] "The G8 Global Partnership against the Spread of Weapons and Materials of Mass Destruction" (Kananaskis, Canada: Government of Canada, 27 June 2002; available at http://www.g7.utoronto.ca/summit/2002kananaskis/arms.html as of 09 July 2007). For a useful summary of the Global

Partnership has had little "global" about it except its name, having focused almost exclusively on projects in Russia (and to a lesser extent Ukraine). Moreover, only a dribble of non-U.S. funds in the Global Partnership has so far been focused on improving nuclear security measures. At the 2007 G8 summit, however, the Global Partnership participants agreed that helping countries worldwide implement measures such as UN Security Council Resolution 1540, the amended physical protection convention, and the new nuclear terrorism convention were legitimate priorities for spending countries' Global Partnership pledges—an important first step.[2]

It may be that a new mission, to contribute to preventing nuclear terrorism throughout the world—and to implementing the other steps to control weapons and materials of mass destruction mandated by UNSCR 1540 (discussed in more detail below)—could convince some states to provide additional contributions. This would finally bring the total up to or beyond the $20 billion initial target and provide sufficient funds to implement the needed steps for all countries requiring assistance worldwide.[3] (As discussed in Chapter 2, the number and magnitude of upgrades needed around the world depends on the level of security set as the target in each country, but it seems likely that substantially less than the $20 billion originally pledged to the Global Partnership would be sufficient to drastically reduce the global danger of nuclear theft and terrorism.) This mission would return the Global Partnership to its original ambitions, which committed participants to take the steps necessary to "prevent terrorists, or those that harbor them, from acquiring" the materials needed for weapons of mass destruction; called on "all countries," not just Russia, to join in providing effective security and accounting for their stockpiles of nuclear weapons and weapons-usable nuclear materials; and offered assistance to any country needing help to provide such security.[4]

The key participants in this campaign should also offer states and facilities strong incentives to provide effective security for their nuclear stockpiles.[5] The United States should work with all states with nuclear stockpiles to ensure that effective and well-enforced nuclear security rules are put in place, giving all facilities with nuclear stockpiles strong incentives to ensure that they are effectively secured—including the possibility of being fined or temporarily shut down if a facility does not follow the rules. It would also be desirable to work to convince states to structure financial and other rewards for strong nuclear security performance (comparable, for example, to the bonus payments contractors managing DOE facilities can earn for high performance). The United States should also establish a preference in all U.S. contracts going to foreign facilities with nuclear weapons or weapons-usable nuclear material (not just those support-

Partnership as of mid-2006, with recommendations for next steps, see *Assessing the G8 Global Partnership: From Kananaskis to St. Petersburg* (Washington, D.C.: Strengthening the Global Partnership Project, Center for Strategic and International Studies, 2006; available at http://www.sgpproject.org/publications/SGPAssessment2006.pdf as of 09 July 2007).

[2] Global Partnership Working Group, "Global Partnership Review" (Heiligendamm, Germany: G8 Summit, June 2007; available at http://www.acronym.org.uk/docs/0706/doc03.htm as of 1 August 2007).

[3] I am grateful to Robert Einhorn for this suggestion. Personal communication, December 2006.

[4] "The G8 Global Partnership against the Spread of Weapons and Materials of Mass Destruction."

[5] Matthew Bunn, "Incentives for Nuclear Security," in *Proceedings of the 46th Annual Meeting of the Institute for Nuclear Materials Management, Phoenix, Ariz., 10-14 July 2005* (Northbrook, Ill.: INMM, 2005).

ing DOE nonproliferation programs) for those which have positively demonstrated effective security performance in realistic tests—and should seek to convince other leading nuclear states to do the same. Ultimately, effective nuclear security should become a fundamental "price of admission" for doing business in the international nuclear market.

Bilateral Cooperation as Part of a Global Campaign

There is still much to be done in Russia to complete the cooperative upgrades now under way, ensure that security measures are put in place that are sufficient to meet the threats that exist in today's Russia, forge a strong security culture, and ensure that high levels of security for nuclear stockpiles will be sustained after international assistance phases out. But increasingly, the work with Russia should become a true partnership of near-equals, framed as one part of a global approach. At the same time, the United States should redouble its efforts to expand its programs to prevent nuclear terrorism across the globe.[6]

U.S.-Russian bilateral cooperation on nuclear security will continue to be critically important for years to come. As President Bush and President Putin acknowledged in their 2005 Bratislava summit statement, as the countries with by far the world's largest nuclear stockpiles, the United States and Russia bear a special responsibility for action. They should seek to take such effective action in securing their own stockpiles that they set a strong example for the rest of the global coalition participants. In addition, they should apply their experience in cooperation (and in their own internal efforts to improve nuclear security) to work together to help other countries around the world to secure their stockpiles.

U.S.-Russian bilateral cooperation on improving nuclear security is coming to a climax, as the two sides have agreed on a joint goal of completing security upgrades at an agreed list of nuclear warhead and material sites by the end of 2008. Even if that goal is met, however, a great deal of work to build effective security cultures, ensure sustainability, address the sites not yet covered by joint cooperation, ensure that security measures are sufficient to defeat the large outsider and insider threats that exist in Russia, and embed all these new measures in effective and effectively enforced nuclear security rules will remain to be done. DOE envisions a period lasting from 2008-2013 during which U.S. funding will decline and Russian funding will phase in, followed by continuing low-level cooperation to exchange best practices and resolve ongoing issues either side may face.[7]

Building on the sustainability agreement reached this year between DOE and Rus-

[6] For an especially useful discussion of specific approaches to strengthening U.S.-Russian nuclear security cooperation through partnership-based approaches, written jointly by U.S. and Russian experts, see U.S Committee on Strengthening U.S. and Russian Cooperative Nuclear Nonproliferation, National Research Council, and Russian Committee on Strengthening U.S. and Russian Cooperative Nuclear Nonproliferation, Russian Academy of Sciences, *Strengthening U.S.-Russian Cooperation on Nuclear Nonproliferation* (Washington, D.C.: National Academy Press, 2005; available at http://fermat.nap.edu/catalog/11302.html as of 09 July 2007). See also Matthew Bunn, "Building a Genuine U.S.-Russian Partnership for Nuclear Security," in *Proceedings of the 46th Annual Meeting of the Institute for Nuclear Materials Management, Phoenix, Ariz., 10-14 July 2005* (Phoenix, Ariz.: INMM, 2005; available at http://bcsia.ksg.harvard.edu/BCSIA_content_stage/documents/inmmpartnership205.pdf as of 09 July 2007).

[7] U.S. Department of Energy, *2006 Strategic Plan: Office of International Material Protection and Cooperation, National Nuclear Security Administration* (Washington, D.C.: DOE, 2006).

sia's Federal Agency for Atomic Energy (Rosatom), Russia and the United States need to move quickly to agree on their approaches to cooperation in 2008 and beyond. In particular, it is very important for the United States to seek a presidential-level Russian commitment to provide the resources needed to sustain high levels of nuclear security in Russia after international assistance phases out—and to ensure that mechanisms are in place to follow up on implementation of that commitment. Since most nuclear managers will not implement security measures they are not required to put in place, effective regulation will be absolutely central to achieving high levels of nuclear security that last for the long haul. Ongoing cooperation with Russia and with other countries must focus intensely on steps to put effective nuclear security regulation in place. It is also important to work to forge strong security cultures. (See discussion of these points below.)

Whether in Russia or in other countries, the goal of cooperation to upgrade nuclear security should not be only to meet a least-common-denominator standard such as the existing IAEA physical protection recommendations, but to achieve a level of security that reduces the risks of nuclear theft to a low level, given the threats that exist in the country in question and the quantity and quality of the nuclear material at the facilities there. In many cases, this may require more substantial upgrades—or more efforts to convince recipient states to provide more numerous and effective guards—than have yet been undertaken.

Adapting the threat-reduction approaches developed in cooperation with Russia and other former Soviet states to the specific circumstances of each other country where cooperation must go forward is likely to be an enormous challenge. Attempts to simply copy the approach now being used in Russia are almost certain to fail.[8] Cooperation with states with small nuclear weapons arsenals, such as Pakistan, India, China, and Israel, is likely to be especially difficult. For all of these states, nuclear activities take place under a blanket of almost total secrecy, and direct access to many nuclear sites by U.S. personnel is likely to be impossible in the near term (an issue discussed in more detail below). In general, working out arrangements to improve nuclear security—and to build confidence that effective nuclear security really is in place—will require considerable creativity and persistence. Providing security equipment and training in such cases in no way contravenes the United States' obligation under the Nonproliferation Treaty (NPT) not to assist non-nuclear-weapon states in acquiring nuclear weapons and can be done in a way that is consistent with all U.S. export control laws as well.

Putting dangerous warheads under jointly monitored lock and key. Tactical nuclear weapons pose a particular danger

[8] For discussion, see "Challenges of Adapting Threat Reduction to New Contexts," in Matthew Bunn and Anthony Wier, *Securing the Bomb: An Agenda for Action* (Cambridge, Mass., and Washington, D.C.: Project on Managing the Atom, Harvard University, and Nuclear Threat Initiative, 2004; available at http://www.nti.org/e_research/analysis_cnwmupdate_052404.pdf as of 2 January 2007), pp. 104-105. See also Lee Feinstein et al., *A New Equation: U.S. Policy toward India and Pakistan after September 11* (Washington, D.C.: Carnegie Endowment for International Peace, 2002; available at http://www.carnegieendowment.org/files/wp27.pdf as of 09 July 2007); James E. Goodby et al., *Cooperative Threat Reduction for a New Era* (Washington, D.C.: Center for Technology and National Security Policy, National Defense University, 2004; available at http://www.ndu.edu/ctnsp/CTR%20for%20a%20New%20Era.pdf as of 25 July 2007); Rose Gottemoeller and Rebecca Longsworth, *Enhancing Nuclear Security in the Counter-Terrorism Struggle: India and Pakistan as a New Region for Cooperation* (Washington, D.C.: Carnegie Endowment for International Peace, 2002; available at http://www.carnegieendowment.org/files/wp29.pdf as of 11 July 2007).

of nuclear theft—and have few reasons to continue to exist, more than fifteen years after the end of the Cold War. While it is unlikely, despite some claims to the contrary, that stolen "suitcase bombs" are available on international black markets, published reports suggest that older tactical nuclear weapons in Russia are not equipped with modern, difficult-to-bypass electronic locks. Some of the forward areas where these weapons are handled are not slated for U.S.-Russian cooperative nuclear security upgrades, and security of warhead transports remains a concern as well. The United States should work with Russia to launch a major initiative to consolidate thousands of U.S. and Russian excess nuclear warheads—especially those that lack modern, difficult-to-bypass electronic locks or electronic sensing devices that prevent them from being armed until after they have passed through an expected flight-to-target sequence that would be difficult for terrorists to duplicate—in secure, jointly monitored storage, and commit them to eventual verified dismantlement.[9]

The Urgency of the Threat: Making the Case

Complacency about the threat is the single biggest obstacle to achieving and sustaining high standards of nuclear security throughout the world. The fundamental key to the success of such a campaign is convincing political leaders and nuclear managers around the world that nuclear terrorism is a real and urgent threat to *their* countries' security, worthy of a substantial investment of their time and money to reduce the danger. If they are convinced, they will take the actions necessary to achieve effective and lasting security for their nuclear stockpiles; if they are not, they will not take the political risks of opening sensitive sites to nuclear security cooperation, give their nuclear regulators the mission and power to enforce effective nuclear security rules, or provide the resources necessary to sustain high levels of security. In maintaining a strong safety system, it is sometimes said that the most important element is never "forgetting to be afraid."[10] The same is even more true for nuclear security.

Today, many of the key players are not afraid. They believe, with Pakistani President Musharraf, that the United States is "overly concerned" about the possibility of nuclear terrorism. The common attitude was well summed up in a private interview with a leading Russian nuclear expert—who had played a key role in establishing cooperation to improve security in the 1990s. Asked about the threat of nuclear theft in Russia today, he leaned back in his chair, took a drag on his cigarette, and said: "I am not worried."[11] Several key steps should be taken to try to build the sense of urgency and commitment among political leaders, nuclear managers, and all key personnel involved in nuclear security.

Joint threat briefings. Upcoming bilateral summits with political leaders of key countries should include detailed briefings for both leaders on the nuclear terrorism threat, given jointly by U.S. experts and experts from the country concerned. These would outline in detail the terrorist desire for nuclear weapons, their

[9] For more discussion of this concept, see Matthew Bunn and Anthony Wier, *Securing the Bomb 2005: The New Global Imperatives* (Cambridge, Mass., and Washington, D.C.: Project on Managing the Atom, Harvard University, and Nuclear Threat Initiative, 2005; available at http://www.nti.org/e_research/report_cnwmupdate2005.pdf as of 02 January 2007), pp. 94-95.

[10] James Reason, *Managing the Risks of Organizational Accidents* (Aldershot, U.K.: Ashgate, 1997), p. 195.

[11] Interview with Kurchatov Institute official, September 2003.

proven efforts to get nuclear weapons, and the very real possibility that terrorists could make at least a crude nuclear bomb if they got the needed nuclear materials. The briefings could also highlight the likely global economic and political effects if a terrorist bomb were to be detonated in a major city, along with the significant reductions in this risk that could be achieved through improved nuclear security measures and other steps.

Nuclear terrorism exercises. The United States and other leading countries should organize a series of exercises with senior policymakers from key states, with scenarios tailored to the circumstances of each country or region where the exercises take place. Participating in such a simulation can reach officials emotionally in a way that briefings and policy memos cannot.[12] Whatever their flaws, for example, the series of "TOPOFF" exercises in the United States appear to have played a significant role in getting top officials focused on preventing and preparing for catastrophic terrorism scenarios, including nuclear terrorism.

Fast-paced nuclear security reviews. The United States and other leading countries should encourage leaders of key states to pick teams of security experts they trust to conduct fast-paced reviews of nuclear security in their countries, assessing whether facilities are adequately protected against a set of clearly-defined threats. In the aftermath of the 9/11 attacks, DOE dispatched a team of security experts to urgently review security measures at all key DOE nuclear sites and make recommendations for improvement. A similar approach of sending out a trusted team for an urgent review had been undertaken several times in the past as well. These reviews have typically identified a wide range of vulnerabilities requiring correction.[13]

These reviews could ask whether the security measures in place are really good enough to defeat, for example, one to three well-placed insiders conspiring to steal nuclear material, or two teams of well-armed and well-trained outside attackers attempting to break in, who might have help from one or more insiders. In many countries, any thorough review would conclude that for some facilities, the answer is decidedly "no." Such reviews could give these leaders an unvarnished, independent assessment, going around those with an incentive to tell them that everything is secure. No U.S. personnel need take part, so there need be no revelation to the United States or other foreigners of any specific security vulnerabilities. But the United States should share, in general terms, the experiences it has had in performing such rapid initial assessments, it should provide training in vulnerability assessment and testing techniques, and, in those countries where assistance may be needed, the United States and other donor states should offer to help cover the cost of any security upgrades the reviews recommend.

[12] The Center for Strategic and International Studies and the Nuclear Threat Initiative (NTI) organized the "Black Dawn" war game in Europe and a similar effort in Moscow. These are very promising first steps; more such games should be conducted, for key officials and facility managers in countries around the world.

[13] In the 1980s, for example, a fast-paced review made hundreds of recommendations for security improvement at DOE, and DOE then launched "Operation Cerberus" (named for the mythical guardian of the gates of hell), a rapid upgrade program that spent more than $1 billion beefing up security at DOE sites. For a discussion, see, for example Committee on Energy and Commerce, *Nuclear Weapons Facilities: Adequacy of Safeguards and Security at Department of Energy Nuclear Weapons Production Facilities*, U.S. Congress, House of Representatives, 99th Congress, 2nd Session, 6 March 1986.

Care should also be taken to structure these reviews, and the incentives of those who carry them out, so that they do not become just another mechanism for complacent nuclear agencies to claim that everything is as it should be without thorough review of whether that is the case. As discussed below, there may also be approaches to providing information from such reviews to other countries that would make it possible to build international confidence that nuclear security was being appropriately addressed without compromising nuclear secrets.

Realistic testing of nuclear security performance. The United States and other leading countries should work with key states around the world to ensure that each country regularly conducts realistic tests of its nuclear security systems' ability to defeat either insiders or outsiders. Each country can carry out these tests with its own personnel, though in some cases states may be willing to allow international participation or observers at such tests to build confidence; U.S. teams conducted such tests in several non-Russian states of the former Soviet Union in the 1990s. A regular system of realistic testing of security performance, where "red teams" playing the roles of outside attackers or insider thieves attempt to overcome the system, can be a critical part of convincing non-expert political leaders that more resources are needed for security. Short of real thefts, nothing demonstrates more convincingly that there is a problem than spectacular failures of defense systems to protect nuclear items in realistic tests. Moreover, if done properly, such tests can help convince guards and other security personnel of the plausibility of the threat, provide important training, and help them find and fix problems that may not have been obvious in paper studies. Such performance testing has been a critical part of improved nuclear security over the past two decades in the United States.[14]

The United States should work with key countries participating in the global coalition to convince them to institute regular realistic testing of nuclear security, briefing them on the U.S. experience, providing training in testing techniques, and offering to cover part of the cost of conducting such tests. In cases like Russia's, where cooperation with U.S. experts is particularly extensive, the United States should seek to help establish joint security testing teams, which could train together, share their techniques, and perhaps carry out joint tests at a few non-sensitive facilities. This would provide both the United States and Russia with a greatly increased understanding of the other side's approach to testing security.

Shared databases of threats and incidents. The United States and other key countries should collaborate to create shared databases of unclassified information on actual security incidents (both at nuclear sites and at non-nuclear guarded facilities) that offer lessons for policymakers and facility managers to consider in deciding on nuclear security levels and the steps required in light of those incidents. Most nuclear managers and staff—even those whose jobs are critical to security—do not receive regular information about terrorist attempts to acquire nuclear materials or nuclear weapons, or other security incidents from which lessons can and should be drawn about the kinds of threats nuclear facilities must be defended against. In 2003, for example, a Russian court case revealed that a Russian businessman had been offering $750,000

[14] For a good account of part of this experience, see Oleg Bukharin, "Physical Protection Performance Testing: Assessing U.S. NRC Experience," *Journal of Nuclear Materials Management* 28, no. 4 (Summer 2000).

for stolen weapon-grade plutonium for sale to a foreign client and had made contact with residents of the closed nuclear city of Sarov in an attempt to get such material.[15] While he did not succeed, the fact that a Russian was offering what was then roughly a century of the average nuclear worker's salary for such material is surely a relevant fact of which security managers should be aware. No Russian nuclear expert or security manager with whom I have discussed this case had ever heard of it before.[16] Similarly, most nuclear security managers around the world would probably be amazed to hear that there really has been a case in the past of more than a dozen heavily armed terrorists overpowering the armed guards at a nuclear facility and seizing complete control of the facility—a type of threat that is often dismissed as unrealistic.[17]

In organizational systems for safety (as opposed to security), keeping track of all such incidents and "near-misses" and the lessons learned from them has proved to be absolutely critical. It is a key part of convincing staff of the need to take safety seriously, and of outlining the specific steps that need to be taken. Indeed, extensive studies have concluded that "the two characteristics most likely to distinguish safe organizations from less safe ones are, firstly, top-level commitment and, secondly, the possession of an adequate safety information system."[18] In the United States, the Institute for Nuclear Power Operations (INPO, the U.S. arm of WANO) distributes detailed analyses of all safety-related incidents to all plants, with accompanying "lessons learned" to avoid such problems in the future. It later inspects each plant's program for reviewing these incidents and implementing the lessons learned.[19]

Although security matters face the constraints of secrecy, in many cases a similar approach can and should be taken for nuclear security. The United States should work with its international partners to establish a shared database of verified information on important security-related incidents and their lessons for the future. Rules could then be put in place requiring facilities to review these incidents and implement the applicable lessons. The incidents included should go beyond the nuclear industry itself. Incidents that confirm the ways that terrorists and thieves have used tactics such as bribing or blackmailing insiders (for example by kidnapping their families), deception (such as fake uniforms and IDs), unusual vehicles, tunnels into secure vaults, and attacks with substantial force and heavy armament would be important for nuclear security managers around the world to understand.[20] Many of these specifics of

[15] Matthew Bunn, "Anecdotes of Insecurity," in *Nuclear Threat Initiative Research Library: Securing the Bomb* (Cambridge, Mass., and Washington, D.C.: Project on Managing the Atom, Harvard University, and Nuclear Threat Initiative, 2004; available at http://www.nti.org/e_research/cnwm/threat/anecdote.asp as of 02 January 2007).

[16] Interviews, May, July, and October 2005.

[17] This was at the Atucha Atomic Power Station in Argentina in 1973. The facility was under construction at the time and had no nuclear material on-site. The terrorists departed as a response force arrived, after a brief shoot-out with the responders. It is not clear that they were ever apprehended. Konrad Kellen, "Appendix: Nuclear-Related Terrorist Activities by Political Terrorists," in *Preventing Nuclear Terrorism: The Report and Papers of the International Task Force on Prevention of Nuclear Terrorism*, ed. Paul Leventhal and Yonah Alexander (Cambridge, Mass.: Lexington Books for the Nuclear Control Institute, 1987).

[18] Reason, *Managing the Risks of Organizational Accidents*, p. 113.

[19] Joseph V. Rees, *Hostages of Each Other: The Transformation of Nuclear Safety since Three Mile Island* (Chicago: University of Chicago, 1996), pp. 128-150.

[20] See Chapter 4 for a discussion of a selection of incidents involving such tactics.

past incidents are not classified and could be included in a database that was available to nuclear facilities around the world. Creating such a threat incident database and ensuring that it was regularly updated and widely used could do a great deal to increase security awareness and strengthen security culture. Such a threat incident database, like many of the other commitment-building steps suggested here, could potentially be implemented by an industry-led security initiative such as the proposed World Institute for Nuclear Security.[21]

Threat-focused training. Ongoing training for nuclear security personnel should highlight the urgency of maintaining high security, ideally in graphic terms that get to the heart, as well as the head. As a related example, as part of the safety training program for all of those involved in building and maintaining U.S. nuclear submarines so that they will not leak, key personnel are required every year to listen to a several-minute audiotape of a submarine that failed, killing everyone aboard.[22] Presentations to policymakers and key nuclear security officials of images from Hiroshima and Chernobyl might similarly highlight, in an emotionally gripping way, the scale of the catastrophe that could occur if nuclear security measures failed and terrorists succeeded in detonating a nuclear bomb or sabotaging a major nuclear facility. The United States and Russia should work together, for example, to develop a training video for nuclear personnel highlighting terrorists' ongoing hunt for nuclear material and the possibility that particularly sophisticated terrorist groups might be capable of constructing at least a crude nuclear bomb.

Effective Global Nuclear Security Standards

As part of this global campaign, President Bush and other leaders of major nuclear weapon and nuclear energy states should immediately seek agreement on a broad political commitment to meet at least a common minimum standard of nuclear security. Effective global standards are urgently needed, for in the face of terrorists with global reach, nuclear security is only as good as its weakest link. The standard should be rigorous enough that all stockpiles with such security measures are well protected against plausible insider and outsider threats, but flexible enough to allow each country to take its own approach to nuclear security and to protect its nuclear secrets. As just mentioned, the agreed global standard might be that all nuclear weapons and significant caches of weapons-usable nuclear materials must be protected at least against a modest group of well-armed and well-trained outsiders (capable of operating as more than one team), one to two well-placed insiders, or both outsiders and insiders working together. While this should be the minimum, in some countries where terrorists and thieves are especially active and capable, security capable of defending against still larger threats should be put in place.

Different countries are likely to take different approaches to meeting the objective. In some countries, an approach focused on large numbers of armed guards may work best; in others, a tech-

[21] For a summary of some of the lessons that might be learned from the 1992 theft of 1.5 kilograms of 90% enriched HEU from the Luch Production Association in Podolsk, Russia, see Matthew Bunn and Anthony Wier, *Securing the Bomb 2006* (Cambridge, Mass.: Project on Managing the Atom, Harvard University, and Nuclear Threat Initiative, 2006; available at http://www.nti.org/securingthebomb as of 23 July 2006), pp. 140-141.

[22] See testimony of Rear Admiral Paul E. Sullivan, Naval Sea Systems Command, in Committee on Science, *NASA's Organizational and Management Challenge*, U.S. Congress, House of Representatives, 29 October 2003.

nology-heavy approach may be more appropriate. Performance in defeating plausible threats is what is important, not the specific means by which that performance is achieved. Hence, a commitment that nuclear stockpiles will be protected at least against a common minimum design-basis threat is likely to be the most effective option for the structure of such a standard.

Gaining Political Commitments

Unfortunately, recent agreements such as the nuclear terrorism convention[23] and the amendment to the physical protection convention,[24] while useful, provide no specific standards for how secure nuclear weapons or weapons-usable materials should be. Efforts to negotiate an effective global nuclear security standard in a treaty have not succeeded in the past and are not likely to succeed in the near-term future, as such negotiations inevitably become bogged down by country representatives who see little urgency for action and considerable potential for added costs and unwanted intrusion for the nuclear industries and ministries they represent.

The most plausible means to overcome such obstacles is for high-level leaders who see the need for a minimum global nuclear security standard, in the interests of all, to quickly put in place a broad political commitment to such a standard. The United States should immediately begin discussions with other leading governments, as a key part of a global nuclear security campaign, on such a political commitment to a common minimum standard.

Using UNSCR 1540

One promising approach to following through on such a high-level political commitment would be to flesh out the specifics of what is required by UNSCR 1540. UNSCR 1540, passed unanimously in April 2004, created a new binding legal obligation on every state to provide "appropriate effective" security and accounting for whatever nuclear stockpiles it may have (along with a wide range of other legal obligations to improve controls over weapons of mass destruction and related materials).[25] Unfortunately, little use of this remarkable tool has yet been made—no government or international organization has yet sought to lay out what an "appropriate effective" nuclear security and accounting system includes or to pressure (and help) states to put those legally required measures in place.

This should change. UNSCR 1540 creates an opportunity for the United States to work with other countries and the IAEA to: detail the essential elements of an "appropriate effective" system for nuclear security; assess what improvements countries around the world need to make to put these essential elements in place; and help (and pressure) countries around the world to take the needed actions. This need not be done through the UNSCR 1540 committee in New York, which has limited capabilities; instead, it could be pursued in meetings at the IAEA, or among the largest nuclear states. If broad agreement could be reached on the essen-

[23] *International Convention for the Suppression of Acts of Nuclear Terrorism* (New York: United Nations, 2005; available at http://www.un.int/usa/a-59-766.pdf as of 25 July 2007).

[24] *Amendment to the Convention on the Physical Protection of Nuclear Material* (Vienna: International Atomic Energy Agency, 2005; available at http://www-pub.iaea.org/MTCD/Meetings/ccpnmdocs/cppnm_proposal.pdf as of 09 July 2007).

[25] The text of UNSCR 1540, along with many related documents, can be found at United Nations, "1540 Committee" (New York: UN, 2005; available at http://disarmament2.un.org/Committee1540/meeting.html as of 09 July 2007).

tial elements of an "appropriate effective" nuclear security system, that would, in effect become a legally binding global standard for nuclear security.[26] Indeed, the entire global effort to put in place stringent nuclear security measures for all the world's stockpiles of nuclear weapons and weapons-usable nuclear materials can be considered simply as the implementation of the unanimously approved obligations of UNSCR 1540.

If the words "appropriate effective" mean anything, they should mean that nuclear security systems could effectively defeat threats that terrorists and criminals have shown they can pose. Thus one possible definition would be that to meet its UNSCR 1540 physical protection obligation, every state with nuclear weapons or weapons-usable nuclear materials should have a well-enforced national rule requiring that every facility with a nuclear bomb or a significant quantity of nuclear material must have security in place capable of defeating a specified design basis threat (DBT) including outsider and insider capabilities comparable to those terrorists and criminals have demonstrated in that country (or nearby). This approach has the following advantages: the logic is simple, easy to explain, and difficult to argue against; the standard is general and flexible enough to allow countries to pursue their own specific approaches as long as they are effective enough to meet the threats; and at the same time, it is specific enough to be effective and to provide the basis for questioning, assessment, and review.[27] The United States and other nations agreeing to such a standard should

[26] For discussion, see Matthew Bunn, "UNSC 1540: Next Steps to Seize the Opportunity," paper presented at A New Role for the United Nations Security Council: Criminalizing WMD Proliferation--The Impact of U.N. Security Council Resolution 1540, Arlington, Va., 15 March 2005 (available at http://bcsia.ksg.harvard.edu/BCSIA_content/documents/UNSC1540.pdf as of 09 July 2007).

[27] Questions designed to clarify a country's compliance with this standard could include such items as: Is there a rule in place specifying that all facilities with nuclear weapons or significant quantities of weapons-usable nuclear material must have security in place capable of defending against specified insider and outsider threats? Are those specified threats big enough to realistically reflect demonstrated terrorist and criminal capabilities in that country or region? How is this requirement enforced? Is there a program of regular, realistic tests, to demonstrate whether facilities security approaches are in fact able to defeat the specified threats? Are armed guards used on-site at nuclear facilities, and if not, how is the system able to hold off outside attack or insider thieves long enough for armed response forces to arrive from elsewhere? Others have proposed other standards to meet similar objectives: Graham T. Allison, for example, has proposed a "gold standard," arguing that given the devastating potential consequences of nuclear theft, all nuclear stockpiles should be secured to levels similar to those used for large stores of gold such as Fort Knox. See Graham T. Allison, *Nuclear Terrorism: The Ultimate Preventable Catastrophe*, 1st ed. (New York: Times Books/Henry Holt, 2004).

In 1994, a committee of the National Academy of Sciences argued that because getting the essential ingredients of nuclear weapons was the hardest part of making a nuclear bomb, plutonium should, to the extent practicable, be secured and accounted for to the same standards applied to nuclear weapons themselves—and argued further that this "stored weapon standard" should be applied to all separated plutonium and HEU worldwide (an approach that presupposes that nuclear weapons themselves have effective protection, which may not always be the case). U.S. National Academy of Sciences, Committee on International Security and Arms Control, *Management and Disposition of Excess Weapons Plutonium* (Washington, D.C.: National Academy Press, 1994; available at http://books.nap.edu/html/plutonium/0309050421.pdf as of 09 July 2007), pp. 31, 102.

Other sources that could also be drawn on for insight in defining the elements of an "appropriate effective" physical protection system include the "principles and objectives" included in the proposed amendment to the physical protection convention (though these are very general and contain few specifics) and the IAEA's recommendations on physical protection (INFIRC/225 Rev. 4). Unfortunately, while both of these provide valuable considerations for physical protection, it is possible

then launch an intensive effort to persuade other states to bring their nuclear security arrangements up to that standard and help them to do so as needed.

The United States should also make clear to all countries where nuclear stockpiles exist that with the passage of UNSCR 1540, providing effective security for these stockpiles is now a legal obligation and a positive relationship with the United States depends on fulfilling that obligation. The United States should also begin discussions with key nuclear states to develop the means to build international confidence that states have fulfilled their commitments to take effective nuclear security measures, without unduly compromising nuclear secrets.

Implementing Multilateral Agreements

Although neither the amendment to the physical protection convention nor the nuclear terrorism convention include specific nuclear security standards, both agreements have the potential to make useful contributions to improving nuclear security and to reducing the risk of nuclear terrorism. The United States should move quickly to ratify these agreements. The United States and other leading countries should step up their efforts to convince all states to ratify these agreements, providing assistance where necessary to help states implement their provisions.

Strengthening IAEA Nuclear Security Recommendations

The current version of the IAEA recommendations on physical protection, INFCIRC/225 Rev. 4, was issued in 1999, long before the 9/11 attacks. As discussed in Chapter 2, its requirements are quite modest. International discussions of another revision are just beginning.[28] The United States and other leading governments should use these talks as another opportunity to build toward commonly followed global standards of nuclear security that would be effective enough to reduce the risk posed by potential nuclear theft to a low level.

Including a minimum design basis threat. INFCIRC/225 Rev. 4 already recommends that states develop a DBT and make it an "essential element" of their physical protection systems.[29] But it does not specify anything about what the DBT should be or how exactly it should be used. The document is almost entirely rule-based, rather than performance-based. A new revision should move in a more performance-based direction, focused on providing capabilities to meet particular threats. Ideally, a new revision should recommend that: (a) states should enact and enforce regulations that will ensure that all facilities and transport legs with Category I material (at least) have security systems in place able to provide

to comply fully with both of them and still not have a secure system.

[28] Interviews with DOE officials, July 2007; with IAEA Office of Nuclear Security official, April 2007; and with State Department officials, July 2006 and October 2006. The new version may be renamed—the IAEA hopes to have it as one entry in its new "Security Series" of publications, giving it a status comparable to the status of the "Safety Series" documents, which have become de facto global standards on a variety of aspects of nuclear safety. On the other hand, a variety of nuclear supply agreements and other accords refer to INFCIRC/225 by name, which may make changing the title difficult.

[29] International Atomic Energy Agency, *The Physical Protection of Nuclear Material and Nuclear Facilities*, INFCIRC/225/Rev.4 (Corrected) (Vienna: IAEA, 1999; available at http://www.iaea.or.at/Publications/Documents/Infcircs/1999/infcirc225r4c/rev4_content.html as of 10 July 2007).

a high probability of defeating the DBT;[30] and (b) that, while DBTs should vary from one state to another depending on the threat, at a minimum all Category I material should be defended at least against a modest group of well-armed and well-trained outsiders (capable of operating as more than one team), with access to inside information on the workings of the security system and the location of the material, against one or two well-placed insiders, or against both outsiders and insiders working together. Whether or not that level of specificity could be achieved, it would also be useful for a new revision of INFCIRC/225 to specify that the DBT in each state should include at least the level of capabilities that terrorists or thieves stealing from major guarded facilities or transports have demonstrated they can pull together in that state, or in neighboring states with similar threat conditions; this would provide a basis for detailed discussions with states about whether their DBTs adequately reflected the threats they had experienced.

The minimum threat suggested above, if agreed to, would represent a very substantial step forward in the way nuclear material is protected around the world. Most countries comply with the recommendations of INFCIRC/225, either because they choose to follow international guidelines, or because a variety of legal requirements oblige them to (in particular, nuclear supply agreements often contain a provision requiring that material be protected at least to the levels called for in INFCIRC/225). The minimum DBT just outlined corresponds roughly to the published version of the U.S. NRC DBT for theft.[31] This DBT is less capable than it should be in a variety of respects and is far less capable than the DOE DBT for identical material;[32] but it represents a level of protection well beyond that which exists today at the most vulnerable facilities with HEU and separated plutonium around the world, and it is the most that could reasonably be hoped for (and possibly more than can actually be achieved) as an agreement resulting from the IAEA's least-common-denominator discussion process.

Because of the likely difficulty of achieving such an objective in that process, the United States should explore this possibility with a number of key like-minded states in advance (as it is now exploring other ideas in the lead-up to formal talks on a revision of INFCIRC/225). If a sub-

[30] To gain sufficiently broad support, it may be necessary to include language that makes it clear that states could choose to achieve this level of performance either through a performance-based approach in which facilities are required to be able to defeat a certain DBT but given significant flexibility in how to go about doing so; a rule-based approach in which the regulations specify particular security measures to be taken, in the expectation that if those measures are taken as specified, the result will be a system that provides protection adequate to defeat the DBT; or a combination of performance-based and rule-based approaches. While a number of states have adopted DBT-centered approaches to physical protection regulation, many others have not, and no state has yet adopted an entirely performance-based approach without a substantial number of rule-based requirements.

[31] See Section 73.1 in U.S. Nuclear Regulatory Commission, "Part 73-Physical Protection of Plants and Materials," in *Title 10, Code of Federal Regulations* (Washington, D.C.: U.S. Government Printing Office; available at http://www.nrc.gov/reading-rm/doc-collections/cfr/part073/full-text.html as of 25 July 2007).

[32] For a more radical argument that INFCIRC/225 should be revised to incorporate a DBT comparable to that now in use at DOE, see Edwin S. Lyman, "Using Bilateral Mechanisms to Strengthen Physical Protection Worldwide," in *Proceedings of the 45th Annual Meeting of the Institute for Nuclear Materials Management, Orlando, Florida, 18-22-July* (Northbrook, Ill.: INMM, 2004; available at http://www.ucsusa.org/global_security/nuclear_terrorism/bilateral-mechanisms.html as of 21 November 2006). Unfortunately, I do not believe that such a far-reaching revision of INFCIRC/225 could be achieved; gaining agreement even on the approach described in the text would be a challenge.

stantial number of the major states had already reached consensus before the formal discussions at the IAEA began, the chances of getting agreement on such an approach would be greatly increased.

Other improvements. A variety of other improvements should be made in INFCIRC/225 as well. A revised document should include additional measures that are focused on the insider threat—likely the dominant theft and sabotage threat in many countries—including more specifics on the need for in-depth background checks and ongoing monitoring of personnel, continuous monitoring of areas with Category I nuclear material (and vital areas in the case of sabotage), training to ensure that all personnel are alert to the possibility of insider theft and know how to report any suspicions they may have, and more. The document should recommend that the actual performance of physical protection systems in defeating both outsider and insider threats be regularly probed with realistic tests in which either test participants portraying outsiders attempt to get in and steal material, or participants portraying insiders attempt to remove material.

If agreement can be reached, it would be highly desirable for the revised document to specifically call for on-site armed guards numerous and effective enough to be able to defeat the DBT. If some states insist on retaining something like the current language allows for "compensatory measures" instead of on-site armed guards, this language should be made more specific, recommending that states not allow the substitution of compensatory measures for armed guards unless the compensatory measures have proved, in realistic tests using teams trained in plausible adversary tactics, that they can provide an equivalent level of protection. The points emphasized in the fundamental principles of physical protection in the amendment to the physical protection convention—including, among others, the importance of security culture—should be included in INFCIRC/225, each with specific recommendations as to how they can be addressed. The very brief discussion of measures to prevent sabotage in the current document should be expanded.

A new approach to categorizing nuclear materials. Finally, the approach to categorizing nuclear material needs to be changed—though this is likely to be difficult, since the categorization table used in INFCIRC/225 is enshrined in the agreed text of the just-amended physical protection convention. The basic principle should be a system which puts the highest priority on securing the material most useful for terrorists seeking to make a nuclear bomb—but does not abruptly drop protection for less-attractive material that terrorists would still have a good chance of making a bomb from. In particular, it is clear that nuclear material emitting 100 rad/hour at one meter is not self-protecting against thieves willing to absorb substantial doses; such material still requires substantial security measures.

If it proves unduly difficult to change the categorization table itself, because of the link to physical protection convention, the already-existing language recommending that states provide security for nuclear materials in proportion to their usability in nuclear explosives could be elaborated and spelled out in more detail; the language indicating that states can reduce the category assigned to nuclear material by one step (for example, from Category I to Category II) if it is emitting 100 rad/hr at one meter (also incorporated in the physical protection convention) could be modified in INFCIRC/225 by adding a recommendation that states should not make this reduction unless compensatory measures were taken to provide equivalent levels of protection against thieves

not concerned with their own health. The U.S. government is already pursuing proposals along this line.[33]

Imposing Tougher Export Requirements

U.S. law requires that nuclear exports not be "inimical to the common defense and security."[34] To date, with respect to the danger of nuclear theft, the United States has only required that states receiving nuclear exports provide security at least equivalent to that called for in the latest IAEA recommendations. U.S. nuclear cooperation agreements with other countries typically reflect these requirements.

But a strong argument can be made that the requirements of INFCIRC/225 Rev. 4 are not enough to prevent nuclear theft risks inimical to the common defense and security.[35] For countries where there are existing nuclear cooperation agreements referring only to the IAEA recommendations, the United States cannot legally demand a higher standard. But there is nothing preventing the United States from launching diplomatic efforts to convince these states that in their own security interests, higher standards of security are needed. Moreover, in compliance with the law, an argument can be made that future exports of HEU or separated plutonium should only be made if they will be handled, as long as they remain in weapons-usable form, with security measures adequate to reduce the risk of nuclear theft and terrorism they pose to very low levels. The United States should take the position that only nuclear facilities with security that has demonstrated high levels of effectiveness can receive U.S. nuclear material or lucrative U.S. government contracts—and should work to convince other leading states to do the same.

In addition, the United States and other leading governments should work to strengthen the guidelines on physical protection of the Nuclear Suppliers Group (NSG). These guidelines, which appear not to have been modified significantly since they were agreed to in 1975, refer to INFCIRC/225 as a "useful basis" for guiding individual states in designing physical protection systems; but the specific measures the NSG members agree to require are considerably weaker than those in INFCIRC/225.[36] More than five years after the 9/11 attacks, it is past time to revise these guidelines so that all major suppliers agree to require physical protection sufficient to defeat the kinds of threats that terrorists and criminals have shown they can pose. Ultimately, as suggested above, good security must become part of the price of admission for operating in the international nuclear market.

[33] Interview with DOE officials, July 2007.

[34] *Atomic Energy Act of 1954, as Amended* (Washington, D.C.: Government Printing Office, 1954; available at http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0980/ml022200075-vol1.pdf as of 07 August 2007)

[35] Edwin S. Lyman, "Using Bilateral Mechanisms to Strengthen Physical Protection Worldwide," in *Proceedings of the 45th Annual Meeting of the Institute for Nuclear Materials Management*, Orlando, Florida, 18-22-July 2004 (Northbrook, Ill.: INMM, 2004; available at http://www.ucsusa.org/global_security/nuclear_terrorism/bilateral-mechanisms.html as of 07 August 2007).

[36] See Appendix C of the NSG guidelines, contained in International Atomic Energy Agency, Communications Received from Certain Member States Regarding Guidelines for the Export of Nuclear Material, Equipment and Technology, INFCIRC/254/Rev. 7/Part 1 (Vienna: IAEA, 2005; available at http://www.nuclearsuppliersgroup.org/PDF/infcirc254r7p1-050223.pdf as of 25 July 2007).

Building Confidence in Nuclear Security

An effort to forge effective global standards should also include steps to build confidence that states have really implemented the agreed nuclear security commitments. Such confidence is critical, as every country has a direct national security interest in making sure that all countries with nuclear weapons and weapons-usable materials provide effective security for them. But building such confidence poses a difficult challenge, as in nearly every country with such stockpiles, the details of nuclear security arrangements are highly classified, making it difficult to reveal enough information to prove that the security measures in place are fully effective.[37]

For those countries willing to accept international peer reviews of their security arrangements, IAEA-led peer reviews can be effective in building confidence. Such peer reviews should increasingly become a normal part of the nuclear business for developed and developing states alike, just as international safety reviews are.[38] But the reality is that some nuclear stockpiles—from those at U.S. and Russian nuclear warhead assembly plants to those in Pakistan and Israel—are extremely unlikely to be welcoming IAEA visitors anytime in the next decade. Graham Allison has proposed that nuclear weapon states invite experts from another nuclear weapon state with which they have good relations to review their nuclear security arrangements and to certify that they are effective. China, for example, which has long had close nuclear relations with Pakistan, might review and certify Pakistan's nuclear security system.[39]

Another approach might focus on providing, at least in general terms, the results of tests of security system effectiveness. The United States, for example, already openly publishes data on what percentage of DOE facilities have received high ratings in DOE security inspections—and uses that percentage as a measure of the effectiveness of ongoing steps to improve security.[40] In the case of U.S.-Russian cooperation, it would be useful to build mutual understanding of what was being tested and how. One approach would be to have some portion of the U.S. and Russian adversary teams used to test the effectiveness of nuclear security systems train together, and perhaps conduct tests with joint U.S.-Russian teams at one or two non-sensitive sites in each country. Then the remaining sites could be tested by purely national teams, using similar

[37] Even at sites in Russia where the United States has invested heavily in improving security, Russia does not inform the United States about operational details of day-to-day security measures important to the effectiveness of the overall system; and the United States has given Russia very little information about the day-to-day effectiveness of U.S. nuclear security systems.

[38] Norway was the first major developed state to request such an international peer review and to encourage all other states to do likewise, arguing that all states can benefit from international advice. Government of Norway, "Statement by Norway," in *48th IAEA General Conference, Vienna, Austria, 20-21 September 2004* (Vienna: International Atomic Energy Agency, 2004; available at http://www.iaea.org/About/Policy/GC/GC48/Statements/norway.pdf as of 10 May 2006).

[39] Allison, *Nuclear Terrorism: The Ultimate Preventable Catastrophe*, pp. 150-153.

[40] See, for example, U.S. Department of Energy, *FY 2006 Congressional Budget Request: National Nuclear Security Administration* (Washington, D.C.: DOE, 2005; available at http://www.cfo.doe.gov/budget/06budget/Content/Volumes/Vol_1_NNSA.pdf as of 10 July 2007), pp. 416-419. Note that in fiscal 2004, the last year whose actual results are reported here, DOE inspectors had rated the security at individual sites "effective" in only 53% of their inspections—and the targets for fiscal 2005 and fiscal 2006 were only to achieve 65% and 70% "effective" ratings, respectively.

approaches and standards, and broad descriptions of the results could be provided to the other country. In the case of tests that revealed vulnerabilities requiring immediate corrective action, U.S. and Russian officials would probably not want to reveal the specifics of those vulnerabilities to the other side until they had been corrected; the existence of such vulnerabilities is considered a secret in each country. In cases where deficiencies were found, they could simply be silent about the results of the test, leaving the other side to draw its own conclusions, until after corrective action had been completed. Such an approach could provide substantially increased confidence to each side that the other's nuclear stockpiles were secure and were being tested effectively. In particular, an approach like this one might be used to confirm that Russia had taken action to provide security at sites that had been judged too sensitive to allow U.S. access that was comparable to the security measures at sites where U.S.-Russian cooperation had taken place, particularly the two remaining nuclear warhead assembly and disassembly facilities.

Approaches such as these are sensible goals to aim for, though they will be extremely difficult to achieve. In the immediate term, states should do more to provide general descriptions of their nuclear security approaches, photographs of installed equipment, and related data that could be made public without providing data that could help terrorists and criminals plan their attacks.

An Industry Initiative to Promote Best Practices

A "security Chernobyl" resulting from a successful sabotage of a nuclear plant or a nuclear theft leading to nuclear terrorism would be both a human catastrophe and a disaster for the global nuclear industry, ending any plausible chance for a large-scale nuclear renaissance. Hence, complementing government efforts, the nuclear industry should launch its own initiative focused on bringing the worst security performers up to the level of the best performers, through defining and exchanging best practices, industry peer reviews, and similar measures—a World Institute for Nuclear Security (WINS), on the model of the World Association of Nuclear Operators (WANO) established to improve global nuclear safety after the Chernobyl accident.

The Nuclear Threat Initiative (NTI) has challenged the Institute for Nuclear Materials Management (INMM) to play a central role in launching such an initiative.[41] In response, a team of INMM experts developed a more detailed concept of how such an organization might function; NTI, INMM, and other stakeholders are now working to bring such an organization into being.

To ensure that such an initiative has the necessary clout, it will be important to develop it in a way that maximizes industry buy-in, particularly from those controlling the purse-strings. What made WANO and its U.S.-based predecessor, the Institute of Nuclear Power Operations (INPO), so effective was that the industry perceived them as its own ideas, operating to serve the industry's own interest. These organizations also had direct access to the utility CEOs, who could bring powerful peer pressure to bear on any CEO whose utility was lagging behind.[42]

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[41] Charles Curtis, "Promoting Global Best Practices," in *Proceedings of the 46th Annual Meeting of the Institute for Nuclear Materials Management, Phoenix, Ariz., 10-14 July 2005* (Northbrook, Ill.: INMM, 2005; available at http://www.nti.org/c_press/speech_curtisINMM_071105.pdf as of 8 June 2006).

[42] For a fascinating discussion of INPO, its record of effectiveness, and the factors that caused that outcome, see Rees, *Hostages of Each Other: The Transformation of Nuclear Safety since Three Mile Island*.

Building Sustainability and Strong Security Cultures

Ensuring that high levels of security will be sustained for the long haul, and that security cultures are strong enough to ensure that equipment will really be used to provide effective security, is absolutely critical to success.

Here again, convincing foreign leaders and nuclear managers of the reality and urgency of the threat is the most important ingredient of success; unless they are convinced that nuclear security is essential to their own security, they are unlikely to take the actions needed to sustain high levels of security, or to build strong security cultures. Convincing security-relevant staff of the reality of the threat and its importance to their country's national security is also a critical step—probably *the* most critical step—in building a strong security culture; steps to make that case were discussed above.

Sustainability

Building on the recent DOE-Rosatom agreement on sustainability, the United States and other leading states should be working with countries around the world to put in place the *resources*, *organizations*, and *incentives* that are required to sustain effective nuclear security for the long haul.

Resources. As a follow-up to the successful Bratislava summit initiative on nuclear security, President Bush should seek an explicit commitment from President Putin that he will assign sufficient resources from the Russian budget to ensure that security and accounting measures sufficient to defeat the threats that terrorists and thieves have demonstrated they can pose in Russia will be sustained after U.S. assistance phases out. Such a commitment should include some mechanism for following through, such as a specific line-item for nuclear security in the Russian state budget.

The possibility of creating a special fund for sustaining nuclear security should also be considered.[43] One possible mechanism would be for the United States and other partner countries to provide funding for sustainability projects that could only be used if matched by dedicated, transparent funds provided from the Russian state budget. At first an exact one-to-one match might not be necessary, but over time, the ratio of donor matching funds to indigenous Russian funding should shift to reflect the increasing ability of Russia to secure its own nuclear warheads and materials against the threats terrorists have demonstrated they can pose. Such a matching fund would require mechanisms to show that work paid for was actually being completed.

As sustainability is not only a Russian problem, similar funding approaches—including Presidential-level commitments to provide the funds needed to sustain effective nuclear security and accounting—should be pursued with other partner countries with large-scale nuclear programs. For countries with only one or two nuclear facilities requiring high levels of security, more limited approaches to

[43] For a proposal for one particular approach to such a fund, see Committee on Indigenization of Programs to Prevent Leakage of Plutonium and Highly Enriched Uranium from Russian Facilities, Office for Central Europe and Eurasia, National Research Council, *Strengthening Long-Term Nuclear Security: Protecting Weapon-Usable Material in Russia* (Washington, D.C.: National Academy Press, 2005; available at http://fermat.nap.edu/catalog/11377.html as of 09 July 2007). For other approaches, see, for example, Matthew Bunn, John P. Holdren, and Anthony Wier, *Securing Nuclear Weapons and Materials: Seven Steps for Immediate Action* (Cambridge, MA: Project on Managing the Atom, Harvard University, and Nuclear Threat Initiative, 2002).

ensuring resources for sustainability are likely to suffice.

Resources other than money—trained personnel, infrastructure to maintain equipment, and more—are also important. The United States and other leading states should seek to ensure that every facility and transport operation with nuclear weapons or weapons-usable material worldwide has all the capacities needed to sustain effective nuclear security, including the necessary procedures, training, and maintenance arrangements. DOE is already focusing on these issues at many sites in Russia; similar efforts need to be made at sites throughout the world.

Organizations. It will be extremely difficult to sustain effective nuclear security unless the organizations responsible have the personnel, expertise, resources, and authority to do so. The United States and other leading states should work to ensure that every facility and transport operation with nuclear weapons or weapons-usable nuclear material worldwide has a dedicated organization charged with ensuring effective security and accounting for those stockpiles. Each of these facilities and transport operations should have sufficient personnel, with sufficient resources and authority, dedicated to this mission. The ministries, agencies, or companies that control these facilities and transport operations should also have appropriate organizations in place to focus on sustaining effective nuclear security.

In particular, the United States should put very high priority on working with partner countries to ensure that all nuclear regulatory bodies have the personnel, expertise, resources, and authority to write and to enforce effective nuclear security and accounting rules. In some cases, this will mean going beyond providing training or equipment to regulatory bodies, to working with political leaders of partner countries to convince them to give their nuclear regulatory bodies enhanced authority or budgets. In the case of Russia, it will mean not only working to strengthen Rostekhnadzor (the regulator for all civilian nuclear activities in Russia) and Rosatom's internal regulation, but also working with the Ministry of Defense (MOD) regulatory group that in principle regulates security for all MOD nuclear activities and for those Rosatom activities involving nuclear weapons and components. Given the prominent role of the U.S. Nuclear Regulatory Commission (NRC) in regulating nuclear security and accounting in the United States, NRC should be given the authority and budget to play a significant role in working with partner countries to set and enforce effective nuclear security and accounting rules.

Incentives. Every dollar a facility manager invests in security is a dollar not spent on something that would bring in revenue or help accomplish the facility's main mission—and every hour a staff member spends following security procedures is an hour not spent on activities more likely to result in a raise or promotion. It is essential to create strong incentives for nuclear security to counteract these obvious incentives to cut corners. Most facility managers simply will not make substantial investments in improving and maintaining security and accounting measures unless they have to. In many cases, "they have to" means that otherwise an inspector is going to come and find out that they have not done so, and the result may be a fine, temporary closure, or something else they want to avoid. Hence, nuclear security regulation is central to effective and lasting nuclear security. The United States and other leading states should seek to ensure that every country with nuclear weapons or weapons-usable nuclear materials has effective nuclear security and accounting rules,

effectively enforced. The United States and other leading states should also take additional steps to ensure that states and facilities have strong incentives to provide effective nuclear security, including establishing preferences in all contracts for facilities that have demonstrated superior nuclear security performance.[44]

Consolidation. Finally, consolidating stockpiles of both nuclear warheads and weapons-usable nuclear materials into a much smaller number of sites (and a smaller number of buildings within those sites) is likely to be crucial to sustainability, because it will make it possible to achieve higher security at lower cost. Detailed consolidation recommendations are provided later in this chapter.

Security Culture

At the same time, the United States and other leading states should do everything possible to build strong security cultures for all organizations involved with managing nuclear weapons and weapons-usable nuclear materials.

Building a real belief in the threat—and its effect on their own country's security—among all security-relevant staff is the fundamental basis of a strong security culture; as noted already, the key is for each organization that handles these weapons and materials never to forget to be afraid. The reality of the threat to be defended against needs to be inculcated constantly—in initial training, annual training, regular security exercises, and by any other means managers can think of. The United States and other leading states should work to ensure that every organization handling nuclear weapons or weapons-usable nuclear material worldwide has a security culture coordinator, providing relevant training and credible, convincing information on the threat and the steps needed to defend against it.

Convincing the top managers (and top security managers) of nuclear facilities is particularly important, for a strong security culture at a facility is only likely to get built if the facility management makes it their personal mission to do so. Promoting an ongoing awareness of security incidents and trends around the world is also key, as only by being confronted with real data on ongoing incidents will people be convinced about the scope and nature of the threats they need to defend against. Indeed, as noted above, tracking and forcing participants to confront such data on problems and near-misses, and the lessons drawn from them, has proven to be absolutely crucial to building effective *safety* cultures in industries throughout the world. Management commitment and a strong system for collecting and learning from information about incidents are likely to be the most important elements of a culture that provides effective security, just as they have proven to be in the case of safety. Incentives for strong security performance—for individual workers, for teams, and for facilities and transporters—are also likely to be an important part of building a culture that takes security performance seriously. Here, too, realistic performance testing and other kinds of simulations and exercises can help convince guards and staff of the reality of the threat and what needs to be done to defend against it. Both the nuclear industry and other industries have broad experience in building strong safety cultures in high-risk organizations; all countries with nuclear weapons or weapons-usable nuclear material should take steps to strengthen security culture that build on that experience. Organizational cultures are difficult to regulate—though some regulators seek to do so, requiring organizations to launch improvement

[44] Bunn, "Incentives for Nuclear Security."

programs when inspections suggest a cultural problem—but regulators can and should insist that organizations implement identified best practices and lessons learned from past problems and incidents. Practices for implementing such lessons learned can serve as indirect indicators of security culture.

An Accelerated and Expanded Global Cleanout

The only foolproof way to ensure that nuclear material will not be stolen from a particular site is to remove it. As a central part of the global campaign to prevent nuclear terrorism, the United States and other leading governments need to work together to accelerate and broaden the effort to consolidate both nuclear weapons and weapons-usable nuclear materials at the smallest practicable number of sites, achieving higher security at lower cost. This effort should focus particularly on removing material from the highest-risk sites—sites that are especially vulnerable and difficult to defend, and sites in especially high-threat countries.

The Global Threat Reduction Initiative (GTRI), launched in the spring of 2004, was established to accomplish that goal—but there is still much to be done to accelerate and strengthen that effort.[45]

The goal should be to remove the weapons-usable nuclear material entirely from the world's highest-risk, least defensible sites within four years—substantially upgrading security wherever that cannot be accomplished—and to eliminate all HEU from civil sites worldwide within roughly a decade.[46] The United States should make every effort to build international consensus that the civilian use of HEU is no longer acceptable, that all HEU should be removed from all civilian sites, and that all civilian commerce in HEU should brought to an end as quickly as possible.[47]

The global coalition described above should seek: to close and decommission HEU-fueled research reactors and other sites with HEU or separated plutonium that are no longer needed; to accelerate conversion of HEU or plutonium-fueled research reactors that will continue to

[45] GTRI is also focused on securing and removing radiological materials that could be used in a so-called "dirty bomb," both within the United States and internationally. That important topic is not the subject of this report, however. For more on reducing radiological threats, see, for example, Matthew Bunn and Tom Bielefeld, "Reducing Nuclear and Radiological Terrorism Threats," in *Proceedings of the 48th Annual Meeting of the Institute for Nuclear Materials Management, Tucson, Ariz., 8-12 July* (Northbrook, Ill.: INMM, 2007); Charles D. Ferguson, Tahseen Kazi, and Judith Perera, *Commercial Radioactive Sources: Surveying the Security Risks* (Monterey, Calif.: Center for Nonproliferation Studies, Monterey Institute of International Studies, 2003; available at http://cns.miis.edu/pubs/opapers/op11/op11.pdf as of 2 August 2007); U.S. Department of Energy, National Nuclear Security Administration, *Strategic Plan: Reducing Nuclear and Radiological Threats Worldwide* (Washington, D.C.: DOE, 2007).

[46] In saying that all the HEU should be removed from the world's most vulnerable sites within four years—a recommendation I have been making for several years—I am *not* suggesting that it is possible to convert every HEU-fueled research reactor within four years. Rather, the argument is that all HEU should be removed from those sites identified as having both (a) enough HEU for a nuclear bomb (or a substantial fraction of that amount), and (b) inadequate security to meet the threats they face, within that time. In some cases, this may mean encouraging reactors that are no longer needed to shut down rather than converting; where neither conversion nor shut-down is realistically possible in a short time span, substantial security upgrades need to be put in place rapidly, sufficient to remove the site from the list of the world's high-risk facilities.

[47] For a similar recommendation, see Charles Ferguson, *Preventing Catastrophic Nuclear Terrorism* (Washington, D.C.: Council on Foreign Relations, 2006; available at http://www.cfr.org/content/publications/attachments/NucTerrCSR.pdf as of 10 July 2007).

operate and for which replacement low-enriched uranium (LEU) fuel is available; to assure that fuels are developed as soon as possible to convert all or nearly all of the remaining still-needed research reactors; and to ensure that effective security is in place (meeting global standards such as those described above) and that both the on-site inventories of HEU and the enrichment of HEU are minimized for those sites where all the HEU cannot be removed immediately.[48]

Success in achieving these goals will require focusing comprehensively on *all* the facilities that have vulnerable weapons-usable nuclear material, not just those that happen to be operating civilian research reactors, or whose nuclear material happens to be Russian-supplied or U.S. supplied. Success will require flexible and creative tactics, with approaches—including incentives to give up the nuclear material—targeted to the needs of each facility and host country. It will also require the United States to convert and adequately secure its own HEU-fueled research reactors, not only to remove such threats from inside U.S. borders but also to enable U.S. leadership in convincing others to do the same.

A Comprehensive Approach to Consolidation

GTRI was explicitly intended to take a comprehensive approach to the problem of insecure nuclear material around the world. GTRI has established an "emerging threats" sub-program which is intended to cover what GTRI refers to as "gap materials"—those materials that fell through the cracks in pre-existing programs. To its credit, DOE has prepared and revised a list of the facilities around the world where weapons-usable nuclear materials exist, to provide the basis for a comprehensive approach, though DOE officials report that as further visits to particular sites are conducted, new facilities using HEU are still being identified.[49] Now, the United States and other leading states should expand the set of reactors they seek to convert or shut down, and the set of potentially vulnerable nuclear material they seek to remove.

An expanded set of reactors. GTRI took a major step in early 2007, expanding adding 23 HEU-fueled reactors to the list of facilities it would like to convert to LEU, bringing the total to 129. (Of these, 48 were already converted or shut down by the end of fiscal year (FY) 2006, leaving 81 remaining on the list targeted for conversion at that time.) But even after this expansion, more than 40% of the research reactors still using HEU fuel are still not covered by the conversion effort. But with an expanded set of tools—including incentives for unneeded reactors to shutdown (discussed in detail below) as well as conversion—many of the remaining difficult-to-convert reactors can and should be addressed. In addition, as discussed below, 95% of the world's supply of the most commonly used medical isotope is still made using HEU irradiation targets, and the major producers so far have little incentive to convert to LEU. Moreover, there are a substantial number of reactors in the world that use HEU as their fuel but are not research reactors, including Russia's nuclear icebreakers; reactors for naval ships and submarines, especially in the United States and Russia;

[48] A similar listing of steps was first proposed in International Panel on Fissile Materials, *Global Fissile Material 2006: Report of the International Panel on Fissile Materials* (Princeton, N.J.: Program on Science and Global Security, Princeton University, 2006; available at http://www.fissilematerials.org/ipfm/site_down/ipfmreport06.pdf as of 09 July 2007).

[49] Interviews with DOE officials, February, April, and December 2005; July 2006; and March and July 2007.

Russia's plutonium and tritium production reactors; and the BN-600 commercial power reactor. Moreover, there are many reactors in the world—primarily in Europe—which use weapons-usable plutonium as their fuel (mixed with uranium in a uranium-plutonium mixed oxide, or MOX), and this practice also poses potential nuclear theft risks wherever the transport and storage of this fuel is not effectively secured. The United States and other leading countries should work to minimize the use of weapons-usable material by *all* reactors, examining each case to see what opportunities exist for convincing responsible officials to shut reactors down or to convert them to fuels and targets made from material that cannot be used in a nuclear bomb. Where neither conversion nor shutdown can be achieved quickly, security and accounting improvements should be put in place to reduce the risks. The United States and other leading states, in short, should vigorously and comprehensively pursue the goal they agreed to at the June 2007 meeting of the Global Initiative to Combat Nuclear Terrorism: "minimizing the use of highly enriched uranium and plutonium in civilian facilities and activities."[50]

Shut-down as an additional policy tool. To date, U.S. efforts to reduce the use of HEU at potentially vulnerable research reactors have focused only on conversion to LEU. Many research reactors, however, are difficult to convert, and most of the world's reactors are aging and underutilized; many of these no longer offer benefits to society that justify their costs and risks. The best answer for many of them is to provide incentives to shut them down. Unlike conversion, shut-down need not wait for the development of new fuels; it can be pursued immediately. For most of the dozens of HEU-fueled research reactors not currently on the target list for conversion (and for many of those that are), the shut-down option would be quicker, less costly, and more likely to succeed than conversion. There is good evidence that such an approach can work, as even in the absence of any effort to provide shut-down incentives, far more HEU-fueled reactors have shut down since 1978, when the effort to convert reactors to LEU began, than have successfully converted.[51] Indeed, IAEA experts have estimated that of the more than 270 research reactors still operating in the world (both HEU-fueled and otherwise), only 30-40 are likely to be needed in the long term.[52]

No research reactor operator wants to shut his or her facility. Convincing those responsible at particular sites to shut down their reactors is likely to require substantial packages of incentives. In some cases, the best route will be through national governments, which may be growing tired of the drain on the budget imposed by subsidizing these reactors and may be more willing to negotiate over these reactors' fate than the operators themselves. As part of such an effort, the international community should help establish a smaller number of more broadly shared research reactors—the same direction that high-energy particle accelerators went long ago. Scientists at sites whose

[50] "Global Initiative to Combat Nuclear Terrorism: Joint Statement" (Washington, D.C.: U.S. Department of State, Office of the Spokesman, 12 June 2007; available at http://www.state.gov/r/pa/prs/ps/2007/jun/86331.htm as of 3 August 2007).

[51] See the data in Ole Reistad, Morten Bremer Maerli, and Styrkaar Hustveit, *Non-Explosive Nuclear Applications Using Highly Enriched Uranium - Conversion and Minimization Towards 2020* (Princeton, N.J.: International Panel on Fissile Materials, 2007).

[52] International Atomic Energy Agency, "New Life for Research Reactors? Bright Future but Far Fewer Projected" (Vienna: IAEA, 8 March 2004; available at http://www.iaea.org/NewsCenter/Features/ResearchReactors/reactors20040308.html as of 5 January 2007).

reactors are shutting down should be given funding and access to conduct experiments at other reactors (as is already routinely done in many countries).

To maintain the trust needed to convince reactor operators to convert to LEU, however, any shut-down effort should be institutionally separate from the conversion effort. DOE's GTRI, in particular, does not feel that it can take the lead on a shut-down agenda.[53] The IAEA, with support from the Nuclear Threat Initiative (NTI), has launched a project focused on encouraging well-utilized and under-utilized research reactors to work together—with the possibility that in some cases under-utilized facilities may decide to close and have their scientists make use of better-utilized and more capable facilities elsewhere. But the IAEA, like GTRI, does not seem to feel that it is in an institutional position to take the lead in offering incentives to convince research reactors to shut down.[54] In short, it is clear what needs to be done, but who should take the lead is less certain. The best approach might be for the United States and other interested countries, in cooperation with the IAEA, to launch a "Sound Nuclear Science Initiative," focused on ensuring that the world gets the highest-quality research, training, and isotope production out of the smallest number of safe and secure reactors at the lowest cost.

As a first step, GTRI and the IAEA should work together to compile data on which research reactors around the world have plenty of business and funding and which do not. (These data are also important because a hardly-used and financially desperate research reactor is far more likely to be insecure.) In addition, GTRI, the IAEA, or a non-government organization should sponsor an in-depth examination of how research, training, and isotope production needs would be met in a world with only 30-40 research reactors (or whatever other number is determined to be needed), and possible paths to reach that destination.

An expanded set of materials. The United States and other leading states should greatly expand and accelerate their programs to take back or otherwise arrange for the disposition of potentially vulnerable HEU and separated plutonium around the world. The focus should be on whether the particular stock poses a security risk, not whether it fits within the stovepipe of a particular program. The goal should be to remove all potential bomb material from sites that cannot easily be effectively secured as rapidly as possible, and to reduce the total number of sites where such material exists to the lowest practicable number. Ultimately, this will involve steps to consolidate stockpiles going well beyond GTRI's current scope; these additional categories of material and approaches to dealing with them are discussed below.

As a first step, while continuing GTRI's sensible approach of seeking ways of addressing materials through commercial arrangements in other countries where possible, the United States should expand its own take-back offer to cover *all* stockpiles of U.S.-supplied HEU, except for cases in which a rigorous security analysis demonstrates that little if any risk of nuclear theft exists. On a case-by-case basis, the United States should also accept other weapons-usable nuclear material that poses a proliferation threat, where other secure disposition paths are not readily available. The United States should seek agreement from Russia, Britain, France,

[53] Interviews with DOE officials, July 2006, March 2007, and July 2007.

[54] Interviews with IAEA officials, March and April 2007.

and other countries to receive and manage high-risk materials when the occasion demands, to share the burden.

Consolidation and security for civilian plutonium. In addition to addressing civilian HEU, the proliferation risks of separated plutonium must be addressed as well. Small quantities of separated plutonium associated with research activities around the world should be addressed by GTRI (as the program currently plans, in a few cases), removing material from vulnerable sites wherever possible and ensuring that materials that remain are effectively secured.

But plutonium is in civil use on a far larger scale than HEU; it is not just a matter of kilograms or tens of kilograms at research facilities, but tens of tons being separated, stored, processed, and used around the world as fuel for large power reactors. While reactor-grade, this material is weapons-usable, and it is essential that security and accounting commensurate with post–9/11 threats be maintained throughout all stages of that process. The large investments in plutonium separation facilities that have already been made make it unlikely that proposals for an immediate moratorium on plutonium reprocessing will be adopted.[55] But the Bush administration should do what it can to discourage the spread of civilian separation and use of separated plutonium and should renew the effort to negotiate a U.S.-Russian moratorium on separating weapons-usable plutonium (a 20-year moratorium was nearly agreed at the end of the Clinton administration, which would have ended the accumulation of over a ton of weapons-usable separated plutonium each year at Mayak). Ensuring that plutonium gets security commensurate with the risks it poses should be a high priority throughout all stages of reprocessing, storage, transport, processing, and use. Over the long term, civilian use of separated plutonium should be phased out, in favor of fuel cycles that do not use weapons-usable separated plutonium.

In announcing its proposed Global Nuclear Energy Partnership (GNEP), which it hopes will ease nuclear waste management and thus contribute to the growth of nuclear energy, the Bush administration agreed that traditional reprocessing approaches that fully separate plutonium pose substantial proliferation risks.[56] The Bush administration argues that its proposed new approaches, variants on UREX+, would be proliferation-resistant, since plutonium would not be separated in pure form but would remain with some of the higher actinides and perhaps the lanthanide fission products as well. Unfortunately, however, studies have suggested that this would offer only a very

[55] For one such proposal, see George Perkovich et al., *Universal Compliance: A Strategy for Nuclear Security* (Washington, D.C.: Carnegie Endowment for International Peace, 2005; available at http://www.carnegieendowment.org/files/UC2.FINAL3.pdf as of 09 July 2007).

[56] Specifically, U.S. Secretary of Energy Samuel Bodman stated, "we all would agree that the stores of plutonium that have built up as a consequence of conventional reprocessing technologies pose a growing proliferation risk that requires vigilant attention." See Samuel Bodman, "Carnegie Endowment for International Peace Moscow Center: Remarks as Prepared for Secretary Bodman" (Moscow: U.S. Department of Energy, 16 March 2006; available at http://energy.gov/news/3348.htm as of 09 July 2007). Critics argue that the waste management approaches proposed in GNEP will undermine rather than promote the future of nuclear energy, asserting that the future of nuclear energy will be brightest if it is made as cheap, simple, safe, proliferation-resistant, and terrorism-resistant as possible, and that reprocessing using past technologies or those proposed in GNEP points in the wrong direction on every count. See, for example, testimony of Matthew Bunn in Committee on Appropriations, Subcommittee on Energy and Water, *Global Nuclear Energy Partnership*, U.S. Senate, 109th Congress, 2nd Session, 14 September 2006.

modest proliferation-resistance benefit.[57] And it seems very likely that if the United States, with the largest number of nuclear power plants in the world, decides to move toward reprocessing, it will make it more difficult to convince states such as South Korea and Taiwan not to do likewise.

The administration argues that by building a commercial consortium that would offer guaranteed fresh fuel and spent fuel management to countries willing to forego enrichment and reprocessing facilities of their own, they will reduce, not increase, the incentives for countries to build their own reprocessing plants. This is a promising approach, but it does not require reprocessing in the United States, which seems much more likely to convince other states to consider reprocessing than to convince them not to do so.

For the near term, the United States should focus those parts of GNEP related to reprocessing only on research and development to determine whether new technologies might be able to overcome the large liabilities of past reprocessing approaches, not on construction of major facilities. And as this research moves forward, the United States should work to ensure that its work in these areas does not encourage the spread of plutonium separation facilities. The United States should reconsider the recent nuclear cooperation agreement with India, which actually requires India to build a new plutonium reprocessing plant.[58]

Consolidation for both civilian and military nuclear materials. While Russian warheads are stored in significantly fewer sites today than they were in Soviet times, and some buildings and sites have had their weapons-usable nuclear material removed, in general consolidation in Russia has lagged. The pace has been slow in part because neither Rosatom nor MOD appears to have been willing to focus on the difficult decisions of closing bases or sites or of forcing them to give up their weapons-usable nuclear material. The United States should increase the priority it devotes to consolidation, and raise the matter with Russia and other countries at higher political levels. The United States should seek to work with Russia to lay out approaches to accomplishing the post-Cold War missions of both countries' nuclear weapons complexes with the smallest possible number of sites and buildings still containing weapons-usable nuclear materials. The United States should also provide detailed briefings on its own consolidation efforts, and the hundreds of millions of dollars in annual safety and security expenditures it expects to save as a result of these efforts. Russia should stop resisting such consolidation and undertake a focused effort to identify facilities that no longer need HEU or plutonium and encourage or force them to allow their nuclear material to be removed. On a much smaller scale, the United States should work with China, France, Britain, Japan, and Germany to pursue consolidation opportunities in these countries as well.

Consolidation for nuclear warheads. The United States should work with Russia to

[57] Jungmin Kang and Frank Von Hippel, "Limited Proliferation-Resistance Benefits from Recycling Unseparated Transuranics and Lanthanides from Light-Water Reactor Spent Fuel," *Science and Global Security* 13, no. 3 (2005).

[58] *Agreement for Cooperation between the Government of India and the Government of the United States of America Concerning Peaceful Uses of Nuclear Energy* (2007; available at http://verificationthoughts.googlepages.com/USIndiaDeal.pdf as of 3 August 2007). See Alexander Glaser, "Neutron-Use Optimization with Virtual Experiments to Facilitate Research-Reactor Converstion to Low-Enriched Fuel," in *Proceedings of the 48th Annual Meeting of the Institute for Nuclear Materials Management,* Tucson, Ariz., 8-12 July 2005 (Northbrook, Ill.: INMM, 2007).

consolidate warheads at a much smaller number of locations.[59] In particular, the United States and Russia should launch a major nuclear warhead consolidation and security initiative, as described above. Leaving the warheads in the vast current number of locations would greatly increase long-term security costs and risks. If existing storage facilities at a small number of sites do not have sufficient capacity to receive warheads from other sites,[60] simple but highly secure bunkers for large numbers of warheads, such as those at the U.S. Pantex facility, could be built in one to two years.

Security upgrades and strengthened security rules, in concert with material removals. As weapons-usable nuclear material cannot be removed from the world's most vulnerable sites overnight, security should be upgraded at these sites for the period before material is removed. Through GTRI or whatever other rubric is most appropriate, the United States should assist countries around the world in strengthening security at small, vulnerable sites with weapons-usable nuclear material—not just to bring them up to a level that meets IAEA recommendations, but to enable them to defend against a substantial enough design basis threat to ensure that the remaining risk of nuclear theft at these sites is low. The United States should also work to ensure that all states with weapons-usable nuclear material (or nuclear weapons) put in place and maintain nuclear security rules requiring that security levels capable of defeating plausible terrorist and criminal threats for all facilities and transport operations where significant caches of weapons-usable nuclear material are present. The cost of complying with such regulations will provide a strong incentive to facilities to get rid of their stocks of HEU or separated plutonium (just as the cost of meeting post-9/11 security requirements have motivated a major consolidation effort at DOE). Hence, the global cleanout and global nuclear security upgrade agendas go hand-in-hand. In particular, those remaining research reactors that are still genuinely needed and cannot convert to available LEU fuels without a substantial degradation of their scientific performance should be effectively secured for now and given incentives to convert when development of new, higher-density LEU fuels is completed—which is not likely to occur until early in the next decade.

Incentives

The United States and other leading countries should provide substantial packages of incentives, targeted to the needs of each facility and host country, to convince those responsible for research reactors to convert from HEU to low-enriched uranium or to shut down and to ship their HEU elsewhere for secure storage and disposition. Such packages could include help with converting to LEU; help with improvements that would make the reactor function even better after conversion than before;[61] help with shutting and de-

[59] For similar recommendations, see Gunnar Arbman and Charles Thornton, *Russia's Tactical Nuclear Weapons: Part II: Technical Issues and Policy Recommendations*, vol. FOI-R—1588—SE (Stockholm: Swedish Defense Research Agency, 2005; available at http://www.foi.se/upload/pdf/FOI-RussiasTacticalNuclearWeapons.pdf as of 09 July 2007); Harold P. Smith, Jr., "Consolidating Threat Reduction," *Arms Control Today* 33, no. 9 (November 2003; available at http://www.armscontrol.org/act/2003_11/Smith.asp as of 09 July 2007), p. 19.

[60] For a discussion of storage capacity constraints as of the late-1990s, see Joshua Handler, *Russian Nuclear Warhead Dismantlement Rates and Storage Site Capacity: Implications for the Implementation of START II and De-Alerting Initiatives*, AC-99-01 (Princeton, N.J.: Center for Energy and Environmental Studies, Princeton University, 1999).

[61] For example, while conversion to LEU can often reduce the neutron flux available for a research reactor's experiments by something in the range

commissioning a reactor; help in securing contracts for other research by the scientists at a site after agreement is reached to shut the site's reactor, including shared use of reactors at other sites; help with managing the wastes from a research reactor; and other steps, many of which will not even be thought of until a particular case arises.[62] Additional incentives are also likely to be needed to convince facilities to return even that portion of the U.S.-supplied HEU abroad that is covered by the current U.S. take-back offer.[63]

Similarly, the United States should take immediate steps to give the four major producers that produce 95% of the world's supply of molybdenum-99 (Mo-99, the most commonly used medical isotope) from HEU irradiation targets incentives to convert to LEU. Although DOE experts and others around the world have developed technologies that make it possible to produce medical isotopes cost-effectively with LEU, and Argentina and Australia, among others, are already doing so,[64] the major producers have little incentive to convert and are concerned that delays and costs from conversion might result in lost market share and profits. The major producers convinced Congress to eliminate the previous restriction in U.S. law limiting exports of HEU for isotope production to producers who had agreed to convert when appropriate processes were available, further reducing their incentives to move toward conversion to LEU.[65] To rectify this situation, Congress should enact new legislation imposing a 30% tax on all medical isotopes produced with HEU, with the revenue to be used to help willing producers convert to LEU. Since the cost of the isotope itself is typically only about 5% of the cost of the medical procedure making use of the isotope, this would have no impact on the availability of medical isotopes and little impact on

of 10%, improved neutron guides—which can be bought for a cost in the range of $1 million—can in some cases increase the neutron flux available at the actual location of the experiments by a factor of ten or more. Where appropriate, GTRI should offer help with purchasing improved neutron guides as part of the conversion process for those reactors willing to convert to LEU. See

[62] Where necessary, this should include help paying for the cost of new LEU fuel (especially in cases were reactor otherwise would not buy new LEU fuel because it already has HEU that will last for many years, or for the lifetime of the reactor).

[63] U.S. Congress, Government Accountability Office, *Nuclear Nonproliferation: DOE Needs to Consider Options to Accelerate the Return of Weapons-Usable Uranium from Other Countries to the United States and Russia*, GAO-05-57 (Washington, D.C.: GAO, 2004; available at http://www.gao.gov/new.items/d0557.pdf as of 10 July 2007). Putting together such packages of incentives will require some broadening of current thinking and an expansion of current budgets (which do not include any funding for incentives going beyond paying the costs of conversion to LEU). Currently, for example, GTRI is willing to help research reactors convert to LEU, so that conversion does not represent a substantial new cost to the reactor operator—but it is generally not willing to make research reactors *better* off than they were before conversion, even if doing so would carry modest cost while being crucial to gaining agreement to convert. This policy should be reversed. GTRI program managers do not want to drive up the price that reactor operators demand for their cooperation, and that is a legitimate issue. But within reason, price should not be allowed to stand in the way of success. U.S. taxpayers would be better served by an $800 million cleanout effort that succeeded in convincing all of the world's most vulnerable sites to give up their weapons-usable material than they would by a $400 million effort that left dozens of vulnerable sites with HEU still in place.

[64] See, for example, George F. Vandegrift, "Facts and Myths Concerning 99-Mo Production with HEU and LEU Targets," in *The 27th International Meeting on Reduced Enrichment for Research and Test Reactors, Boston, Mass., 6-10 November 2005* (Argonne, Ill.: Argonne National Laboratory, 2005; available at http://www.rertr.anl.gov/RERTR27/PDF/S8-1_VandeGrift.pdf as of 12 July 2007).

[65] For a caustic account of the lobbying campaign that led to this result, see Alan J. Kuperman, "Bomb-Grade Bazaar," *Bulletin of the Atomic Scientists* 62, no. 2 (March/April 2006; available at http://www.thebulletin.org/article.php?art_ofn=ma06kuperman as of 20 June 2006), pp. 44-50.

medical costs, but it would make producers using HEU much less competitive and give them strong incentives (and assistance) to convert.[66]

Conversion, Shut-Down, and Security Upgrades in the United States

If the United States wants to convince other countries to convert their research reactors to use fuels that cannot be used in nuclear weapons, to put rules in place requiring high security for those facilities where HEU is still present, and to ensure stringent security for all potential nuclear bomb material, whether in military or in civilian use, it needs to be willing to do the same itself. In particular, the United States should convert all U.S. HEU-fueled research reactors to LEU as soon as possible—a worthwhile move on its own, but also one likely to be an essential element of convincing foreign reactors to convert. If the United States is unwilling to phase out its own civilian use of HEU and provide stringent security for all uses of HEU and separated plutonium, there is little likelihood that it will be able to convince others to do so. Fortunately, as described in Chapter 2, in recent years the United States has begun to take important steps in this direction, with new conversions of university research reactors, and shut-downs of unneeded DOE reactors. But there is more to be done. DOE should continue to provide the funding needed to convert U.S. HEU-fueled research reactors as rapidly as practicable. The NRC should phase out the exemption from most physical protection requirements for HEU that research reactors currently enjoy and should modify its rule exempting HEU emitting 100 rad/hr or more at one meter from virtually all security requirements. DOE, which pays most of the cost of operations at university-based research reactors in any case, should agree to pay the increased security costs. DOE should carefully examine its own research reactor fleet and consider whether more of these facilities can be shut down, converted to LEU, or at least converted to less-enriched HEU.

High-Level, High-Priority Diplomacy

In the past, conversion of research reactors to LEU and removal of HEU from vulnerable sites have in most cases been handled by program managers and technical experts, not by cabinet or subcabinet national security officials. They have been treated, in essence, as "nice to do" nonproliferation initiatives, not as urgent national security priorities deserving of attention from the highest levels. In part as a result, discussions with those responsible for many reactors around the world have dragged on for years, often with the hope that agreement to convert the reactor is just around the corner, but with the final deal never quite getting done. If the United States is now to succeed in drastically increasing the pace of HEU removals around the world, the issue will likely need to be on the agenda of senior officials, as one critical element of the global effort to keep nuclear bomb material out of terrorist hands and therefore a high priority for U.S. diplomacy.[67]

[66] This sensible approach was first suggested to me by an individual who was then a DOE official, is now a U.S. national laboratory employee, and prefers to remain anonymous.

[67] This high-level approach is already being taken, for example, in the effort to convince Ukraine to allow the HEU to be removed from its facilities: while that effort has not yet produced agreement, the chances are better than they would have been if cabinet secretaries had not been weighing in.

4 BEYOND NUCLEAR SECURITY

This report has focused on improving security for nuclear stockpiles, as that is the single policy step that can do the most to reduce the risk of nuclear terrorism. The countries that possess nuclear weapons and materials know where they are and can take action to secure them effectively if they have the ability and motivation to do so: the key policy problem is providing motivation and resources where they are lacking, but necessary to finishing the job.

Intervening earlier on the terrorist pathway to the bomb—when terrorists are plotting, but have not acquired the nuclear weapon or material needed to carry out an attack—requires successfully detecting and disrupting highly secretive terrorist activities, or addressing the factors that allow terrorists to recruit the people and to acquire the resources needed for a nuclear effort. There have been successes in these areas, but each of these endeavors are difficult and depend a great deal on luck; there is always the danger that a cell working to carry out a nuclear terrorist attack will succeed in keeping its activities secret until it is too late.

Intervening later on the terrorist pathway to the bomb—after a nuclear weapon or the material to make one has already been stolen, and is no longer under the control of any government—is an even greater challenge, as, once stolen, nuclear weapons or materials could be anywhere, and everything that might be done to find and recover them, or prevent their use, is a variation on looking for a needle in a haystack.

Nonetheless, because efforts to lock down nuclear stockpiles around the world are not likely to be 100% successful—and because some undetected thefts of nuclear material may already have occurred—the world should make some investment in other lines of defense. Under the Global Initiative to Prevent Nuclear Terrorism, the participants agree to improve nuclear security and accounting, but they also agree to take steps in other areas to reduce the nuclear terrorism risk, including improving their abilities to detect and search for nuclear and radioactive materials; strengthening their capacities to respond to nuclear emergencies; and-preventing "provision of safe haven… or economic resources" to potential nuclear terrorists.[1]

Disrupt: Counter-terrorism Efforts Focused on Nuclear Risks

Counter-terrorist efforts that succeeded in reducing both the number of groups that could plausibly pursue nuclear terrorism and the effectiveness of the remaining ones could substantially reduce the risk of nuclear terrorism, even if they were only partly successful.[2] The United States and other leading governments should continue and expand their efforts to identify

[1] "Statement of Principles by Participants in the Global Initiative to Combat Nuclear Terrorism" (Washington, D.C.: The White House, Office of the Press Secretary, 31 October 2006; available at http://www.state.gov/r/pa/prs/ps/2006/75405.htm as of 22 December 2006).

[2] For discussion, see Matthew Bunn, "A Mathematical Model of the Risk of Nuclear Terrorism," *Annals of the American Academy of Political and Social Science* 607 (September 2006).

and destroy terrorist groups with the combination of extreme objectives, propensity to mass violence, demonstrated ability to plot and carry out complex attacks, international reach, and substantial financial and technical capabilities that might make them plausible candidates for nuclear terrorism. They should also make a determined effort to identify and track possible observable indicators of nuclear weapons activities—not only statements about nuclear matters and explicit attempts to get nuclear material or expertise,[3] but also related activities such as the purchase of induction furnaces and high-temperature crucibles suitable for casting uranium or plutonium, training in shaped explosives suitable for explosive lenses, suspicious chemical leaks or fires, and more.[4]

Terrorist efforts to recruit people with relevant expertise—such as nuclear physicists, metallurgists, or uranium machinists—may be one of the more detectable activities associated with a nuclear weapons effort. To increase awareness of this potential problem (and increase the chance that such recruitment attempts would be reported), police and intelligence agencies should seek to build relationships at locations that may pose particular opportunities for such recruiting efforts, including technical universities in countries such as Pakistan or Egypt, universities elsewhere in the world where extremists appear to be active among the student body, or nuclear research centers with underpaid scientists who have poor morale. They should widely disseminate information about easy and anonymous ways to report on any suspicious activities (coupled with a program of rewards for doing so). They should also keep track of cases of conspicuous wealth among nuclear scientists and engineers that do not seem to match these individuals' salaries.

Since such activities could occur anywhere in the world, a sustained nuclear counter-terrorism effort cannot succeed without a substantially increased effort to cooperate with intelligence and police services around the world toward these objectives—including improving other countries' efforts (and ability) to monitor indicators of terrorist nuclear interest and activity.

While a terrorist nuclear bomb assembly effort would not require large fixed facilities and might occur in a developed country, it is clear that a terrorist-dominated failed state such as the Taliban's Afghanistan would offer would-be nuclear terrorists a greater ability to work uninterrupted at fixed facilities for prolonged periods, increasing their chances of success. It would be effectively impossible to detect most indicators of such an effort in such a state. Hence, international efforts to rebuild failed states (including devoting greater resources to preventing Afghanistan from sliding back in that direction), avoid future failed states, and help countries gain control over "stateless zones," if successful, would also help reduce the risk of nuclear terrorism.[5]

[3] It would be useful, as just one example, to track purchases of books such as *The Los Alamos Primer* and views of particularly informative websites by individuals in countries with active terrorist organizations, or by individuals on relevant watch lists.

[4] For an unclassified summary of a classified study on the prospects for improving capabilities to detect such indicators (which is much more optimistic on the subject than I am), see Michael V. Hynes, John E. Peters, and Joel Kvitky, "Denying Armageddon," *Annals of the American Academy of Political and Social Science* 607 (September 2006).

[5] The CIA has publicly warned of the terrorist dangers posed by an estimated 50 such stateless zones in countries around the world. See testimony of then-Director of Central Intelligence George Tenet in Committee on Armed Services, *Current and Future Worldwide Threats to the National Security of the United States*, U.S. Senate, 108th Congress, 2nd Session, 9 March 2004.

The United States and other leading governments should also work closely with governments that have nuclear stockpiles and face severe threats from terrorists and thieves—such as Russia and Pakistan—to attempt to reduce the scale of those threats. Tougher screening and monitoring of nuclear insiders, anti-corruption programs focused on the nuclear complex, cooperation to improve government capabilities to detect and stop large-scale conspiracies before attacks occur, and efforts to change the conditions that allow terrorist groups to thrive in these countries could significantly reduce the probability that terrorists or thieves would be able to put together sufficient capabilities to carry out a successful nuclear theft. In other words, efforts to reduce the probability of nuclear theft should focus not only on upgrading the defense but also on reducing the threat.

At the same time, it is worth making a major effort to change the conditions that make it easier for extreme Islamist terrorist groups to recruit and raise funds—to reduce the dangers of all forms of terrorism, not just nuclear terrorism.[6] If the hatred of the United States and the West and the tolerance for terrorism that have become distressingly commonplace in much of the Islamic world could be changed, through a combination of changes in policies and more effective engagement with the Islamic world, it would have little effect on people who are already hard-core terrorists, but it might significantly undermine their ability to put together the sophisticated technical expertise and substantial resources needed for a nuclear weapons effort. A lasting resolution of the Israeli-Palestinian conflict, an end to the U.S. domination of Iraq, and consistent efforts that contribute to justice and development in the Islamic world could potentially counter the hatred and sense of hopelessness that create fertile ground for terrorist recruitment and fundraising.

In particular, a targeted discussion of the moral illegitimacy of mass violence on a nuclear scale under Islamic law and other religious traditions—coupled with providing detailed information on just how horrifying the effects of nuclear weapons truly are—could make it more difficult for those terrorists wanting to pursue nuclear violence to convince the people they need to join their cause. After 9/11, bin Laden spent a great deal of his public statements justifying the mass slaughter of innocents (including some Muslims), in response to criticisms from prominent Islamic scholars that indiscriminate killing is forbidden under Islamic law. Awareness of such concerns may have been what provoked bin Laden to seek a *fatwa* from a radical Saudi cleric holding that the use of nuclear weapons against U.S. citizens was permissible. If successful, convincing al Qaeda's many audiences that the use of weapons of mass destruction against civilians is a crime that cannot be justified under any circumstances might do as much to reduce the danger of nuclear terrorism as any other step.[7]

[6] The effort to "diminish the conditions" that lead to terrorism is one of the key elements of U.S. counterterrorism strategy, but as has been widely noted, it is the one where the United States has been least successful. See, for example, discussion in Bruce Hoffman, *Does Our Counter-Terrorism Strategy Match the Threat?* CT-250-1 (Santa Monica, Calif.: RAND, 2005; available at http://www.rand.org/pubs/testimonies/2005/RAND_CT250-1.pdf as of 28 December 2006). For the beginnings of a set of recommendations for changing this, see, for example, Daniel Benjamin and Steven Simon, *The Next Attack: The Failure of the War on Terror and a Strategy for Getting It Right* (New York: Times Books, 2005).

[7] Of course, the United States is the only country that has ever used nuclear weapons against civilians, and continues to maintain that nuclear use is legitimate under some circumstances, a situation that inevitably makes it more difficult for the

It would be particularly worthwhile to engage in such a discussion at the places where the physicists and metallurgists for a bomb program are most likely to be recruited—at nuclear facilities and universities in countries with sophisticated terrorist groups, with Pakistan at the top of the list. Indeed, a broader engagement with the community of nuclear scientists and engineers around the world is needed to build a global norm that sees cooperation with terrorist groups on nuclear matters for what it is—a crime against humanity. Professional societies, universities, national academies of science, and other institutions can play a key role in building such a global norm and encouraging nuclear experts to report any suspicious activities or enquiries.

Interdict: Countering the Nuclear Black Market

The United States and other leading governments should take additional steps—beyond preventing nuclear theft in the first place—to make it even more difficult than it already is for potential thieves with access to nuclear material and potential terrorist buyers to find each other and complete a successful transaction. Intelligence and law enforcement agencies should run additional stings and scams, posing, for example, as sellers of nuclear material and expertise, to catch participants in this market, collect intelligence on market participants, and increase the fears of real buyers and sellers that their interlocutors may be government agents.[8] Furthermore, these efforts should be well publicized, to create even greater uncertainty among potential buyers. Intelligence agents from the United States and other leading nations should also work with the semi-feudal chieftains who control some of the world's most dangerous and heavily-smuggled borders, to convince them to let their contacts know if anyone tries to move nuclear contraband through their domains.[9]

Most of the confirmed cases in which stolen weapons-usable nuclear material was successfully seized by authorities involved one of the conspirators or someone they tried to involve in the effort informing on the others. Hence, additional measures to make such informing more likely—including anonymous tip hotlines or websites that were well-publicized in the nuclear community, and rewards for credible information—could also have substantial benefit. All potential source states and likely transit states should have units of their national police force trained and equipped to deal with nuclear smuggling cases, and other law enforcement personnel should be trained to call in those units as needed.[10]

Current efforts to put in place radiation detection at key border crossings (and

United States to convince others of the moral illegitimacy of nuclear weapons.

[8] Stings in which government agents pose as nuclear material buyers are also possible (and have been pursued in the past), but run the risk of creating the impression of market demand for stolen nuclear material and possibly provoking nuclear material thefts.

[9] William Langewiesche, "How to Get a Nuclear Bomb," *Atlantic Monthly* 298, no. 5 (December 2006), pp. 80-98. While many of the specific factual assertions in this article are incorrect, this suggestion makes a good deal of sense.

[10] For discussions arguing, similarly, for a greater emphasis on post-theft intelligence and police interventions to reduce the threat of nuclear terrorism, see, for example, Rensselaer Lee, "Nuclear Smuggling: Patterns and Responses," *Parameters: U.S. Army War College Quarterly* (Spring 2003; available at http://carlisle-www.army.mil/usawc/Parameters/03spring/lee.pdf as of 5 December 2005); Rensselaer Lee, *Nuclear Smuggling and International Terrorism: Issues and Options for U.S. Policy*, RL31539 (Washington, D.C.: Congressional Research Service, 2002).

to improve nuclear detection within the United States) may also reduce the risk somewhat, forcing smugglers to pursue more difficult and chancier routes. The Domestic Nuclear Detection Office (DNDO), established in 2005, is focused on improving U.S. capability to detect nuclear and radiological material coming into the United States, and within the United States—as well as designing a "global detection architecture" to be implemented by other agencies.[11] In late 2006, Congress passed legislation requiring every container entering the United States through the 22 ports handling the largest numbers of U.S.-bound containers to be scanned for radiation by the end of 2007;[12] reportedly, some 90 percent of containers entering the United States are already subject to such scans.[13] Unfortunately, such requirements for 100% scanning, without standards for how effective such scanning should be or a systems approach to blocking other smuggling routes, may lead to hurried deployment of systems that are less than optimally effective.

DOE's "Second Line of Defense" program is now playing the leading role in deploying such radiation detectors in other countries. The program currently intends to install such detectors at 450 border crossings and 75 "megaports" in key countries around the world by the end of 2014, and had such detectors operational at 98 border crossings and 6 megaports by the end of fiscal year (FY) 2006.[14] In mid-2007, the DOE reached agreement with Russia to complete installation of radiation detection equipment at hundreds of Russian border crossings by the end of 2011—and for Russia to pay roughly half the cost of doing so.[15]

But as noted in Chapter 1, such passive detectors would have little chance of detecting shielded HEU (unless it was contaminated with U-232 and the detectors were designed to look for those gamma rays), and smugglers have a vast range of different methods available for smuggling items as small as the nuclear material for a bomb, many of which would never go near a nuclear material detector. Hence, it is unlikely that such border-detection and internal-detection

[11] For a discussion, see, for example, Committee on Homeland Security, Subcommittees on Prevention of Nuclear and Biological Attack and Emergency Preparedness, Science, and Technology, *Detecting Nuclear Weapons and Radiological Materials: How Effective Is Available Technology?* U.S. House of Representatives, 109th Congress, 1st Session, 21 June 2005.

[12] *Security and Accountability For Every Port Act of 2006*, Public Law 347, 109th Congress (October 13, 2006, available at http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=109_cong_bills&docid=f:h4954enr.txt.pdf as of June 15, 2007). http://www.thompsonhine.com/news/nl/Oct06_Transportation_3.pdf

[13] See, for example, Steve Coll, "The Unthinkable: Can the United States Be Made Safe from Nuclear Terrorism?" *The New Yorker* 83, no. 3 (12 March 2007; available at http://www.newyorker.com/reporting/2007/03/12/070312fa_fact_coll as of 07 May 2007), pp. 48-57.

[14] Data provided by DOE, September 2007. These goals represent a major increase in ambition compared to what DOE planned to accomplish as recently as early 2007. See U.S. Department of Energy, *FY 2008 Congressional Budget Request: National Nuclear Security Administration* (Washington, D.C.: DOE, 2007; available at http://www.cfo.doe.gov/budget/08budget/Content/Volumes/Vol_1_NNSA.pdf as of 03 March 2007), p. 474.

[15] Department of Energy, "All of Russia's Border Crossings to be Outfitted with Proliferation Prevention Equipment," (1 June 2007; available at http://www.nnsa.doe.gov/docs/newsreleases/2007/PR_2007-06-01_NA-07-21.htm as of June 15, 2007); and Carl Giacomo, "U.S., Russia Agree on Nuclear Detection Plan," *Washington Post*, 1 June 2007. It appears that something in the range of 90% of the targeted border crossings are at Russia's borders; in its release, DOE reports that it is working to install detectors at some 350 border crossings in Russia, out of 380 total border crossings worldwide.

measures will reduce the probability of successful nuclear terrorism by more than a few percentage points.[16]

To gain the maximum benefit from such measures, a systems-engineering approach is needed, looking not just at how well an individual detector may perform, but what options adversaries would have to defeat the system—by choosing other routes, bribing officials to get past dectectors, hiding nuclear material in difficult-to-search cargoes, and other means—and what options the defense might have for countering those adversary tactics.[17] Based on such an analysis, the United States and other leading governments should pull existing efforts together into a prioritized strategic plan that goes well beyond detection at borders. Such a plan would detail what police, border, customs, and intelligence entities are needed in which countries, with what capabilities, by when—and what resources will be used to achieve those objectives.

It will not be possible to interdict nuclear smuggling without broad international cooperation, especially between police and intelligence agencies. The smuggling networks are international: the effort to stop them must be international as well. U.S.-Russian intelligence cooperation in this area, in particular, needs to be substantially strengthened—there are many relevant incidents that occur in Russia that the U.S. government finds out about months later, if at all (and the reverse may be true as well). With each agency mistrusting the others, such cooperation is never easy—but given the threat, it is essential to find ways to push past the barriers to making such cooperation work.

To deter nuclear thieves and smugglers, it is also crucial to ensure that they get appropriate penalties. Many countries either do not have any laws specifically relating to theft, unauthorized possession, or smuggling of nuclear and radioactive materials, or have laws that impose penalties no greater than those for stealing a car. Given the potential consequences of nuclear theft and smuggling, the United States and other leading states should work to ensure that all states pass and enforce laws making actual or attempted theft of a nuclear weapon or weapons-usable nuclear material, unauthorized transfers of such items, or actual or attempted nuclear terrorism crimes with penalties comparable to those for treason or murder.

Prevent and Deter: Reducing the Risk of Nuclear Transfers to Terrorists by States

As discussed in Chapter 2, deliberate decisions by hostile states to provide nuclear bomb materials to terrorists are a smaller part of the danger of nuclear terrorism than nuclear theft, because regimes focused on their own survival know that any such act would risk overwhelming retaliation.[18] Nevertheless, steps should be taken to reduce this element of the risk of nuclear terrorism as well. The United States should seek to reduce this

[16] For a discussion of measures in this area and their strengths and weaknesses, see Anthony Wier, "Interdicting Nuclear Smuggling," in *Nuclear Threat Initiative Research Library: Securing the Bomb* (Cambridge, Mass., and Washington, D.C.: Project on Managing the Atom, Harvard University, and Nuclear Threat Initiative, 2002; available at http://www.nti.org/e_research/cnwm/interdicting/index.asp as of 1 March 2005).

[17] For a discussion of such approaches, see Michael Levi, *On Nuclear Terrorism* (Cambridge, Mass.: Harvard University Press, forthcoming).

[18] For a discussion of how much different pathways to acquire nuclear weapons or materials may contribute to the overall risk, see Bunn, "A Mathematical Model."

risk through a combination of deterrence, disarmament, and efforts to make such transfers more difficult to carry out.

First, the United States should announce that it will treat any terrorist nuclear attack using a weapon or material deliberately provided by a state as an attack by that state and will respond accordingly. The United States should also emphasize publicly that it is making every effort to improve its capability to attribute the source of nuclear material in such an event.[19]

Second, the United States should abandon its reluctance to engage directly with Iran and its reluctance to offer serious incentives to North Korea, working with other leading governments to gain international agreement on packages of carrots and sticks that are large and credible enough to convince Iran and North Korea that it is in their interests to verifiably abandon their nuclear weapons efforts. (Unlike North Korea, as far as is known Iran does not currently have weapons-usable nuclear materials that could be transferred even if it chose to do so—except for a few kilograms of irradiated HEU that the United States provided for the Tehran Research Reactor in the Shah's time.[20]) For there to be any hope of long-term success in either of these cases, the United States will have to make it very clear that if these governments comply with their nuclear obligations and do not commit or sponsor aggression against others, the United States will not attack them or attempt to overthrow or disrupt their regimes; in both cases, U.S. approaches that seem bent on undermining the regime strengthen hard-liners who argue that compromise is pointless because the United States will never accept the continued existence of their governments.[21]

Third, the United States and other leading governments should also take steps to ensure that states in a position to transfer nuclear weapons or material do not become sufficiently desperate that such transfers might be seen either as the last chance for regime survival or the last chance to punish those whose actions led to the regime's collapse. It is precisely such circumstances that create the greatest dangers. In the lead-up to the Iraq war, for example, U.S. intelligence assessed that Saddam Hussein would be unlikely to consider helping terrorists attack the United States unless he was convinced his regime was about to be overthrown in any case; only as a "last chance to extract vengeance," the CIA concluded, would even Saddam's regime consider the "extreme step" of helping terrorists with weapons of mass destruction.[22] (Fortunately for the world, by the time of the war Saddam's regime had no such weapons and the issue did not arise.)

Fourth, the United States and other leading states should avoid actions that would increase the probability of state collapse

[19] For discussions emphasizing this approach, see, for example, Michael Levi, "Deterring Nuclear Terrorism," *Issues in Science and Technology* 20, no. 3 (2004; available at http://www.issues.org/20.3/levi.html as of 28 December 2006); William Dunlop and Harold Smith, "Who Did It? Using International Forensics to Detect and Deter Nuclear Terrorism," *Arms Control Today* 36, no. 8 (October 2006; available at http://www.armscontrol.org/act/2006_10/CVRForensics.asp as of 28 December 2006).

[20] This research reactor has since been converted to run on LEU, with help from Argentina (since no help was available from the United States after the 1979 revolution).

[21] See, for example, Ray Takeyh, "Take Threats Off the Table Before Sitting With Iran," *Boston Globe*, 3 May 2007.

[22] George J. Tenet, "Letter to Senator Bob Graham" (Washington, D.C.: U.S. Central Intelligence Agency, 7 October 2002; available at http://www.globalsecurity.org/wmd/library/news/iraq/2002/iraq-021007-cia01.htm as of 6 March 2006).

in any country with nuclear weapons, and should affirmatively take steps to reduce that danger where possible. Any collapse of a nuclear-armed state could create deadly "loose nukes" dangers. In particular, collapse of the North Korean regime would drastically increase the risk that some portion of North Korea's plutonium or even its weapons might fall into terrorist hands.[23] State failure in Pakistan would also pose an immense risk of nuclear assets falling into the hands of jihadi terrorists.

Fifth, the United States should work to make it more difficult and risky for states such as North Korea or Iran to transfer nuclear weapons or weapons-usable nuclear material beyond their borders. This would include working with China and other states bordering North Korea to beef up border controls and nuclear detection capabilities at key border crossings (an effort that was just beginning as of late 2006[24]), attempting similar efforts with neighbors of Iran and Pakistan[25] (an even more difficult problem, given the scale of all the smuggling that has traditionally taken place across these loosely controlled borders), and continued efforts to beef up international collaborations focused on blocking such transfers, such as the Proliferation Security Initiative (PSI). As just discussed, however, there should be no assumption that such efforts to interdict transfers will accomplish more than a modest increase in the probability of successful transfers. Blocking transfers of material that could fit in a suitcase, across hundreds or thousands of kilometers of often essentially unmarked and uncontrolled borders, is an extraordinary challenge.

Respond: Global Nuclear Emergency Response

Within the United States, the Nuclear Emergency Support Team (NEST, formerly the Nuclear Emergency Search Team) is charged with searching for and disabling a terrorist nuclear bomb, in the event of an explicit threat or other information suggesting that such an attack may be imminent.[26] NEST teams would also be called on to search for and attempt to recover nuclear material if a major nuclear theft occurred within the United States. NEST teams are equipped with sophisticated nuclear detection equipment and specialized technologies which, it is hoped, would make it possible to disable even a booby-trapped bomb before it detonated. Because of the great difficulty of detecting nuclear material at long range, broad-area searches are not practicable (though there are some hopes that future technology might someday make broad-area searches possible for plutonium with minimal shielding, if not for HEU); if the only information available was that

[23] Ashton B. Carter, William J. Perry, and John M. Shalikashvili, "A Scary Thought: Loose Nukes in North Korea," *Wall Street Journal*, 6 February 2003. The North Korean military and Communist Party, who control the nuclear assets, are the closest thing to functioning institutions that exist in North Korea, and may well be the last elements remaining in the event of state collapse; but the dangers of such a collapse scenario would nevertheless be immense.

[24] Interview with DOE official, December 2006. Such detectors are reportedly already in place at key points along the Russian portion of North Korea's borders, however. Giacomo, "U.S., Russia Agree on Nuclear Detection Plan."

[25] Pakistan's current government is supporting some U.S. anti-terrorist efforts, but Pakistan is clearly a plausible location from which either a future government or a terrorist group might attempt to transfer nuclear material beyond the state's borders.

[26] For a summary of NEST and its history, see, for example, Jeffrey T. Richelson, "Defusing Nuclear Terror," *Bulletin of the Atomic Scientists* 58, no. 2 (March/April 2002; available at http://www.thebulletin.org/article.php?art_ofn=ma02richelson as of 28 December 2006), pp. 38-43. See also Coll, "The Unthinkable: Can the United States Be Made Safe from Nuclear Terrorism?"

there was a nuclear bomb somewhere in a particular city, the chances of finding it would be slim. But if additional information made it possible to narrow the search to an area of a few blocks, the chances of finding it would be substantial.

The United States should work with other countries to ensure that an international rapid-response capability is put in place—including making all the necessary legal arrangements for visas and the import of technologies such as the nuclear detectors used by the NEST team (some of which include radioactive materials)—so that within hours of receiving information related to stolen nuclear material or a stolen nuclear weapon anywhere in the world, a response team (either from the state where the crisis was unfolding, or an international team if the state required assistance) could be on the ground, or an aircraft with sophisticated search capabilities could be flying over the area.

Stabilize: Stabilizing Employment for Nuclear Personnel

With Russia's economy stabilized, most nuclear workers in Russia are now paid an above-average wage, on time; the desperation of the late 1990s has largely eased. The situation at many nuclear facilities has substantially stabilized.[27] With thousands of nuclear workers soon to lose their jobs as major facilities close, however, serious proliferation risks remain. In early 2005, for example, a group of Russian Strategic Rocket Forces officers—people who had spent their careers working with nuclear weapons and presumably know a great deal about security arrangements for them—became so desperate after having been left behind with their families in a remote garrison when the missile base was closed down that they agreed to bypass the Ministry of Defense and petition the United States directly for assistance.[28] Moreover, it appears that participating in scientific cooperation funded by the United States and European countries may reduce scientists' willingness to participate in proliferation countries' weapons programs irrespective of economic desperation.[29] In short, despite the economic improvements in Russia, there is clearly still a case for continuing with efforts to engage personnel with potentially dangerous knowledge—not only in Russia, but in countries such as Libya and Iraq as well. The threat is not just nuclear weapons scientists who might help a foreign state develop a nu-

[27] For an excellent update on the status and future of Russia's nuclear complex as of 2004, see Oleg Bukharin, *Russia's Nuclear Complex: Surviving the End of the Cold War* (Princeton, N.J.: Program on Science and Global Security, Woodrow Wilson School of Public and International Affairs, Princeton University, 2004; available at http://www.ransac.org/PDFFrameset.asp?PDF=bukharinminatomsurvivalmay2004.pdf as of 8 March 2005). If anything, the situation in Russia's nuclear complex has improved further since then, with substantial increases in federal spending on both nuclear weapons and civilian nuclear energy. It is important to note, however, that these improvements are not universal -- and in particular that many experts with sensitive chemical, biological, missile, and conventional weapons knowledge may not have experienced similar improvements.

[28] "US Money Lost on Way to Former Russian Army Servicemen," trans. BBC Monitoring Service, *Ekho Moskvy*, 15 February 2005; Aleksey Terekhov and Yevgeniy Latyshev, "Russian Missile Officers to Petition US for Resettlement Aid," *Novye Izvestiya*, 14 February 2005. I am grateful to Charles L. Thornton for pointing this incident and its significance out to me.

[29] Surveys have found that foreign financing for civilian work reduces scientists' reported willingness to cooperation with proliferation programs in developing countries, but Russian financing for civilian work does not -- suggesting that money to address economic desperation may not be the key causal factor. See Deborah Yarsike Ball and Theodore P. Gerber, "Russian Scientists and Rogue States: Does Western Assistance Reduce the Proliferation Threat?" International Security 29, no. 4 (Spring 2005).

clear bomb, but nuclear workers or guards who might help thieves steal the essential ingredients of a bomb.[30]

The United States should work closely with Russia and other countries to take a broader approach, using all the economic tools available, to revitalizing the economies of those nuclear cities where the major facilities are closing or shrinking and to reemploying other nuclear workers and experts who could otherwise pose a proliferation threat.[31] In Russia, such efforts should not be limited to the closed nuclear cities, but should be pursued for personnel at open sites as well.

Individuals who have left the nuclear facilities where they once worked but may still have proliferation-sensitive knowledge should be targeted by such programs, as they have not been before. This should include retired guards and nuclear material workers who still know the details of the security arrangements at sites with nuclear weapons or weapons-usable nuclear materials, many of whom face rather grim economic conditions. In the case of current nuclear guards, the approach should focus less on the U.S.-sponsored job creation programs than on working with countries where nuclear stockpiles exist to ensure that they fulfill their responsibility to provide guard forces with appropriate numbers, training, equipment, commitment, and compensation. The United States should work to convince the Russian government, in particular, to increase the effectiveness of, and reduce the insider threats posed by, the conscript Ministry of Interior guard forces that guard most nuclear sites, ideally moving to the use of well-trained and well-paid volunteer guards at these critical facilities (a practice Russia already follows at nuclear warhead storage sites).[32]

Reduce: Reducing Stockpiles and Ending Production

In addition to securing nuclear material at sites and removing material from especially vulnerable sites, steps should also be pursued to destroy weapons-usable nuclear material and avoid the accumulation of ever-larger stockpiles. A building with one ton of nuclear material poses as great a theft threat as a building with 100 tons of nuclear material, so reductions in the sheer size of nuclear stockpiles may have limited effects in reducing theft risks (however worthwhile they may be for other reasons) unless they are targeted toward achieving that purpose.

One targeted stockpile-reduction approach the United States should pursue would focus on those nuclear warheads whose features to prevent unauthorized use if they are stolen are weakest. A substantial fraction of Russia's remaining tactical nuclear warheads are believed not to have modern difficult-to-bypass electronic locks to prevent unauthorized use, and in some cases these warheads are

[30] For a useful discussion, see John V. Parachini and David E. Mosher, *Diversion of NBC Weapons Expertise from the FSU: Understanding an Evolving Problem* (Santa Monica, Cal.: RAND, 2005).

[31] See "Chapter 12, Stabilizing Employment for Nuclear Personnel," in Matthew Bunn, Anthony Wier, and John Holdren, *Controlling Nuclear Warheads and Materials: A Report Card and Action Plan* (Cambridge, Mass., and Washington, D.C.: Project on Managing the Atom, Harvard University, and Nuclear Threat Initiative, 2003; available at http://www.nti.org/e_research/cnwm/cnwm.pdf as of 2 January 2007), pp. 141-146.

[32] For an alarming discussion of the weaknesses of these guard forces from an official Russian source, see Igor Goloskokov, "Refomirovanie Voisk MVD Po Okhrane Yadernikh Obektov Rossii (Reforming MVD Troops to Guard Russian Nuclear Facilities)," trans. Foreign Broadcast Information Service, *Yaderny Kontrol* 9, no. 4 (Winter 2003; available at http://www.pircenter.org/data/publications/yk4-2003.pdf as of 28 February 2005).

stored at remote, difficult-to-defend storage sites.[33] The United States and Russia should launch another round of reciprocal initiatives, comparable to the Presidential Nuclear Initiatives of 1991-1992, but with two critical differences: this round should be focused particularly on reducing risks of nuclear theft, and it should include some monitoring to confirm that the pledges are kept. As part of such an initiative, the United States and Russia should exchange information on how many tactical nuclear warheads they have, they should discuss means of reducing this number as much as possible, and they should ensure that all nuclear weapons are stored in facilities with the highest practicable levels of security. In particular, the United States and Russia should each agree to: (a) take several thousand warheads—including all of those posing the greatest risk of theft[34]—and place them in secure, centralized storage; (b) allow visits to those storage sites by the other side to confirm the presence and the security of these warheads; (c) commit that these warheads will be verifiably dismantled as soon as procedures have been agreed by both sides to do so without compromising sensitive information; and (d) commit that the nuclear materials from these warheads will similarly be placed in secure, monitored storage after dismantlement.[35]

If effective security can be provided throughout the process, it would also make sense to destroy much more of Russia's stockpiles of HEU than the 500 tons covered by the current U.S.-Russian HEU Purchase Agreement, which expires in 2013. Russia has made clear that it will not renew the existing agreement (which

[33] Gunnar Arbman and Charles Thornton, *Russia's Tactical Nuclear Weapons: Part I: Background and Policy Issues*, vol. FOI-R—1057—SE (Stockholm: Swedish Defense Research Agency, 2003); Gunnar Arbman and Charles Thornton, *Russia's Tactical Nuclear Weapons: Part II: Technical Issues and Policy Recommendations*, vol. FOI-R—1588—SE (Stockholm: Swedish Defense Research Agency, 2005; available at http://www.foi.se/upload/pdf/FOI-RussiasTacticalNuclearWeapons.pdf as of 12 April 2005); Anatoli Diakov, Eugene Miasnikov, and Timur Kadyshev, *Non-Strategic Nuclear Weapons: Problems of Control and Reduction* (Moscow: Center for Arms Control, Energy, and Environmental Studies, Moscow Institute of Physics and Technology, 2004; available at http://www.armscontrol.ru/pubs/en/NSNW_en_v1b.pdf as of 17 March 2005).

[34] Ultimately all nuclear warheads not equipped with modern electronic locks should be dismantled. In the near term, however, neither side is likely to be willing to dismantle all such warheads, as U.S. strategic ballistic missile warheads, the centerpiece of the U.S. deterrent, are not equipped with such locks integral to the warheads, and the same is believed to be true of some warheads critical to the Russian deterrent. In general, however, warheads on submarines or on ICBMs in concrete silos pose a lesser risk of theft than warheads scattered in forward-deployed storage facilities. In particular, while these warheads may not have electronic locks requiring insertion of a particular code to arm them, they are typically equipped with devices that will not allow them to be armed until they have experienced the expected acceleration of ballistic missile flight followed by a period of coasting through space; while these devices were designed for safety, not security, they would make it quite difficult for a terrorist group not aided by someone familiar with their details to set off a stolen weapon, as discussed in Chapter 2. Hence, for the immediate initiative, for all warheads not equipped with modern electronic locks, each side should either (a) include them in the set subject to secure, monitored storage and eventual verified dismantlement, or (b) provide the other side with sufficient information to build confidence that they are highly secure. Where warheads not equipped with modern electronic locks are not in immediate use, and are not mounted on SLBMs or ICBMs—as when they are being kept as spares, for example—they should be stored in partly disassembled form, ideally with critical parts in separate locations, to make them more difficult to steal.

[35] For an earlier description of this idea, see, for example, Bunn, Wier, and Holdren, *Controlling Nuclear Warheads and Materials*, pp. 132-134. For an up-to-date discussion of the risks posed by tactical nuclear weapons and steps to reduce them, see William Potter and Nikolai Sokov, "Practical Measures to Reduce the Risks Presented by Non-Strategic Nuclear Weapons," paper presented at The Weapons of Mass Destruction Commission, Stockholm2005 (available at http://www.wmdcommission.org/files/No8.pdf as of 18 April 2005).

is being implemented in a way that Russia finds financially unattractive). But with both uranium and enrichment services becoming scarce and expensive, there may be substantial opportunities for Russia to profit from blending down additional HEU to LEU for use in its planned domestic reactors, or for sales on international markets. A variety of options are available to ensure that the release of additional Russian material would not crash prices or undermine the investments essential to long-term sustainable supply.[36]

There are also opportunities for the United States and other countries to offer increased access to their uranium and enrichment markets and other tools—including, for example, providing some of their comparatively rich depleted uranium "tails" for use in producing blendstock for blending down HEU—to encourage Russia to destroy hundreds of tons of additional HEU. There may also be opportunities, through relatively modest capital investments in expanding capacity, to accelerate the rate of blending beyond the current 30 tons of HEU per year, so that the security benefit of destroying additional HEU does not have to wait until well beyond 2013 to be achieved. The United States, for example, could pay Russia a fee for blending HEU to 19% enriched LEU, which would be placed in monitored storage under agreed arrangements under which it would be released onto the market only under conditions that would not undermine stable long-term prices.[37]

At the same time, if high standards of security are maintained throughout, it would be worthwhile to move forward as quickly as possible with safe, secure, and transparent disposition of excess weapons plutonium. Disposition of the 34 tons of Russian excess plutonium and the 34 tons of U.S. excess plutonium covered by the U.S.-Russian Plutonium Management and Disposition Agreement will only be a substantial contribution to U.S. and international security, however, if it is the first step toward a much larger reduction in the stockpiles of weapons plutonium that now exist.[38] In July 2007, Thomas D'Agostino, the acting administrator of the National Nuclear Security Administration, said publicly that DOE plans to declare additional plutonium to be excess and available for disposition—a potentially valuable next step, depending on how much plutonium is added to the amount considered excess.[39]

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[36] For a discussion, see Nuclear Threat Initiative and Atominform, Joint Conceptual Analysis and Cost Evaluation of the Possibility of Accelerated Disposition of Highly Enriched Uranium No Longer Needed for Defense Purposes (Washington, D.C.: NTI, 2005; available at http://www.nti.org/c_press/analysis_HEUfinalrpt.pdf. as of 17 August 2007).

[37] New optimization studies by experts from the Russian facilities doing the blending work, sponsored by the Nuclear Threat Initiative, suggest that the initial capital investments required might be significantly less than earlier studies suggested. See Laura S.H. Holgate and Robert Schultz, "Optimized Options for Accelerated Downblending of Excess Russian Highly Enriched Uranium," in *Proceedings of the 48th Annual Meeting of the Institute for Nuclear Materials Management, Tucson, Arizona, 8-12 July 2007* (Northbrook, Ill.: INMM, 2007). While these studies envision investment in expanded Russian enrichment capacity for producing blendstock, this would not be required if Russia were blending HEU for use on its own domestic market, or if the HEU were blended to 19% and then the enrichment content of the 19% stockpile was used for meeting the demands of existing customers. For an earlier description of such proposals, see Bunn, Wier, and Holdren, *Controlling Nuclear Warheads and Materials*.

[38] For an elaboration of this point, see Matthew Bunn, testimony in Subcommittee on Strategic Forces, Committee on Armed Services, *Plutonium Disposition and the U.S. Mixed Oxide Fuel Facility*, U.S. House of Representatives, 109th Congress, 2nd Session, 26 July 2006 (available at http://www.house.gov/hasc/schedules/ as of 10 August 2006).

[39] H. Josef Hebert, "Administration Plans to Convert More Plutonium to Commerical Fuel," *Associated Press*, 19 July 2007. To date, there has been no formal announcement of specific amounts of ad-

Efforts to end the accumulation of stockpiles of weapons-usable nuclear material should also be pursued, particularly if they have ancillary benefits for reducing the dangers of nuclear theft and terrorism. If a verified and global fissile material cutoff treaty (FMCT) could be achieved, for example, this would not only end further additions to the stockpiles of plutonium and HEU available for weapons, but would likely bring to an end a substantial amount of bulk processing of plutonium and HEU (one of the stages of the material life-cycle that is most vulnerable to insider theft), and the verification would impose a multilateral discipline on the quality of material control and accounting that is not present at military facilities in the nuclear weapon states today.[40] The United States should reverse its misguided opposition to a verified fissile cutoff, and lead work with other governments to overcome the obstacles to negotiating such a treaty—including the possibility of undertaking negotiations outside of the Conference on Disarmament if that body continues to be unable to move forward.[41]

The United States and other countries are also working with Russia to provide alternative heat and power sources so that Russia's last plutonium production reactors can shut down. Like the FMCT, this would also lead to the end of a large quantity of bulk processing of plutonium and HEU each year (both at the reprocessing plants that recover the plutonium produced in these reactors and at the facilities that produced HEU spike fuel for these reactors—which is also transported over thousands of kilometers from the fabrication facilities). These reductions in bulk processing would reduce the danger of nuclear theft from these facilities. At the same time, though, the impending closure of these facilities means that thousands of workers who have access to plutonium today know that they will soon be losing their jobs, which may increase temptations for nuclear theft. If this effort is to have net security benefits worth its very substantial costs, the participating countries should put high priority on working with Russia to ensure that the displaced workers receive either suitable employment or secure retirement packages and that high levels of security—including against insider threats—are maintained throughout these facilities' remaining life.

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ditional excess plutonium. Russia, unfortunately, has not made similar commitments to declare more plutonium excess, despite its much larger plutonium stockpile.

[40] I am grateful to William Walker for making this point to me. Personal communication, March 2003.

[41] Matthew Bunn, "Fissile Material Cutoff Treaty," in *Nuclear Threat Initiative Research Library: Securing the Bomb*, ed. Matthew Bunn and Anthony Wier (Cambridge, Mass., and Washington, D.C.: Project on Managing the Atom, Harvard University, and Nuclear Threat Initiative, 2004; available at http://www.nti.org/e_research/cnwm/ending/fmct.asp as of 2 January 2007).

5 GETTING THE JOB DONE

None of the initiatives recommended in this report will be easy. The low-hanging fruit in efforts to reduce the danger of nuclear terrorism has already been plucked. Keeping nuclear weapons and their essential ingredients out of terrorist hands will require broad international cooperation affecting some of the most sensitive secrets held by countries around the globe. Getting the job done will require a sea-change in the level of sustained leadership from the highest levels of government around the world (including the United States); an integrated and prioritized plan; and the resources and information needed to carry out the plan.

Sustained Leadership—And a Single Leader

A maze of political and bureaucratic obstacles must be overcome—quickly—if the world's most vulnerable nuclear stockpiles are to be secured before terrorists and thieves get to them. This will require sustained political heavy lifting coming from presidents and prime ministers in many countries, focused on overcoming obstacles and on moving these programs forward as rapidly as possible.

There is no substitute for U.S. leadership: the United States is the country most concerned about the nuclear terrorist threat, the country prepared to devote the largest resources to reducing it, the country that invests most heavily in securing its own large stockpiles, and hence the country with the most extensive experience in modern systems-engineering approaches to nuclear material protection, control, and accounting (MPC&A).

While President Bush has rightly said that preventing nuclear terrorism must be the nation's top priority, he has focused only intermittently on cooperation to improve nuclear security, the most potent available tool to reduce the risk. The substantial results when he has been engaged—such as the acceleration of work following the Bush-Putin nuclear security summit accord at Bratislava in 2005—hint at what could be accomplished with a sustained push from the Oval Office.

The U.S.-Russian interagency nuclear security committee established by the Bratislava summit, co-chaired by Secretary of Energy Samuel Bodman and his Russian counterpart, Rosatom chief Sergei Kirienko, represents a major step in the right direction. This committee has succeeded in reaching agreement on a plan for completing upgrades at all but a few Russian nuclear weapon and weapons-usable material sites by the end of 2008 and on a plan for returning most Soviet-origin HEU to Russia by the end of 2010. Those agreed timetables, coupled with a requirement to report to President Bush and President Putin every six months on progress in meeting them, have focused managers' minds on moving these efforts forward as quickly as possible; indeed, the Bush administration has repeatedly asked for and received supplemental appropriations to provide the funds needed to meet the Bratislava deadlines. In other words, the post-summit process is having precisely the desired effect: forcing managers to do everything they can to move the targeted efforts forward. The twice-yearly reports to the U.S. and Russian Presidents also provide a regular mechanism that could be used to bring

key issues forward for presidential decision (though it does not appear to have been used for that purpose to date).

But the reality is that the necessary programs stretch across multiple branches of government—in the United States, in Russia, and in other nuclear weapons states and nuclear energy states around the world. Many of the obstacles are not ones that a Secretary of Energy or a Rosatom chief can realistically overcome; for better or for worse, neither of these agencies are at the center of decision-making on matters of security, diplomacy, or secrecy and counter-intelligence in their respective governments. Nuclear agencies inevitably take the lead on implementation, but they need sustained help from the centers of political power to overcome the obstacles they face and to seize new opportunities as they arise.

To ensure that this work gets the priority it deserves, President Bush should appoint a senior full-time White House official, with the access needed to walk in and ask for presidential action when needed, to lead these efforts and keep them on the front burner at the White House every day. That official would be responsible for finding and fixing the obstacles to progress in the scores of existing U.S. programs scattered across several cabinet departments of the U.S. government that are focused on pieces of the job of keeping nuclear weapons out of terrorist hands —and for setting priorities, eliminating overlaps, and seizing opportunities for synergy.

Despite creating a Department of Homeland Security, President Bush rightly considered it essential to retain a senior official in the White House focused full-time on homeland security—to ensure that the issue continued to get the needed sustained White House attention and to use the power of the president to overcome the obstacles to progress and to eliminate the disputes between the departments and agencies that continue to play essential roles. More recently, President Bush realized that integrating and pushing forward the military, diplomatic, and nation-building strands of his administration's approach to Iraq and Afghanistan required a full-time leader in the White House, and he appointed Lieutenant General Douglas Lute to take on that task. President Bush recognized that leaving it in the hands of his national security advisor would either mean that there would not be enough attention to all the disparate elements of both war efforts, or that everything else would get short shrift. This same logic applies in the necessity for a full-time White House official dedicated to preventing nuclear terrorism.

The fate of the Mayak Fissile Material Storage Facility (FMSF) provides one graphic example of the need for such an official empowered to sweep aside bureaucratic obstacles. The FMSF is a giant secure fortress for storing excess plutonium, built in Russia with over $300 million in U.S. funds, completed in 2003. As a result of a variety of disputes over transparency, adequate staffing, and other issues, it sat empty for three long years, with the first plutonium loaded in the summer of 2006 (with the transparency issues still not resolved).[1] These were three years that were taking place after the

[1] For an announcement of the initial loading of plutonium in July 2006, see "Nuclear Storage Facility Commissioned in Russia's Chelyabinsk Region," *ITAR-TASS*, 11 July 2006. For accounts of some of the disputes about the facility, see Matthew Bunn, "Mayak Fissile Material Storage Facility," in *Nuclear Threat Initiative Research Library: Securing the Bomb* (Cambridge, Mass., and Washington, D.C.: Project on Managing the Atom, Harvard University, and Nuclear Threat Initiative, 2004; available at http://www.nti.org/e_research/cnwm/securing/mayak.asp as of 2 January 2007); Carla Anne Robbins and Anne Cullison, "Closed Doors: In Russia, Securing

9/11 attacks and after Russian officials had acknowledged that terrorist teams were scoping nuclear weapon storage facilities in Russia; half of the time was after the Bratislava summit had focused presidential attention on accelerating progress on nuclear security. Faster mechanisms for overcoming obstacles and escalating disputes to higher levels when necessary are urgently needed.

As part of this sustained leadership from the top, nuclear security needs to be at the front of the diplomatic agenda. Despite myriad statements about the priority of the issue, there is little public indication that the subject of preventing nuclear terrorism—and in particular taking urgent steps to secure nuclear stockpiles around the world—has been a focus of any but two of President Bush's meetings with foreign leaders, or of more than a handful of Secretary of State Condoleezza Rice's meetings with her counterparts. The subject was entirely absent from the summit-level U.S.-India nuclear deal, despite the fact that DOE experts had been attempting to engage India on nuclear security cooperation for years. No public discussion of Chinese leader Hu Jintao's April 2006 visit to Washington mentioned the subject, even though DOE has placed high priority on trying to extend nuclear security cooperation with China, but has not yet succeeded in getting Chinese agreement to expand beyond the civil sector.

If an effective global coalition to prevent nuclear terrorism is to be forged, this has to change. The leaders of the critical states need to hear, at every opportunity, that action to ensure nuclear security is crucial to their own security and to a positive relationship with the United States.

Its Nuclear Arsenal Is an Uphill Battle," *The Wall Street Journal*, 26 September 2005.

The United States can no longer afford to let the issue languish when obstacles are encountered, or to leave the discussion to specialists. The United States government should make nuclear security a central item on the diplomatic agenda with all of the most relevant states, an item to be addressed at every opportunity, at every level, until the job is done.[2]

An Integrated, Prioritized Plan of Action

Literally dozens of different programs in several different agencies of the U.S. government are addressing one aspect or another of reducing the threat of nuclear terrorism. Yet today, there is no integrated plan linking these efforts together, no systematic means of identifying opportunities for synergy or gaps or overlaps to be corrected, and little effort to prioritize which of these efforts are most important. When Congress passed legislation requiring the administration to prepare a prioritized plan for securing the world's most dangerous facilities, what they got

[2] The experience in Russia has been that cooperation has proceeded best when either (a) it was allowed to go forward "under the radar screen," with technical experts communicating directly with each other with relatively modest intervention from central governments, or (b) at the other extreme, when action was taken at the presidential level to push the cooperation forward and overcome obstacles. When the discussion was lodged at levels in between those extremes, officials who wanted to raise objections were able to do so, and officials who wanted to sweep aside these obstacles did not have the power to do so. Matthew Bunn, "Cooperation to Secure Nuclear Stockpiles: A Case of Constrained Innovation," *Innovations* 1, no. 1 (2006; available at http://bcsia.ksg.harvard.edu/BCSIA_content/documents/INNOV0101_CooperationtoSecureNuclearStockpiles.pdf as of 4 April 2006). In the case of countries such as Pakistan, India, and China, however, it appears likely that nuclear security cooperation will be so sensitive and so closely monitored by conservative government security agencies, that the "under the radar screen" approach may not be possible.

were three prioritized lists from three of DOE's programs —even within DOE, the programs were unable to agree on a consolidated set of priorities, let alone doing so between DOE and other agencies.[3]

One of the first jobs of a senior White House official to lead these disparate efforts must be to establish priorities and put together a plan that includes objectives to be achieved, assignment of responsibility for different aspects of achieving them, milestones for progress, and the resources needed to get these jobs done. That official must then hold managers accountable for making the progress needed, for quickly identifying obstacles to progress and possible ways to resolve them, and for finding opportunities for new progress and ways to take advantage of them.

Of course, this is not a problem the United States can or should address unilaterally. Contributions are needed from many countries around the world—and these are inevitably difficult to predict. Nevertheless, the contributions of other countries and the diplomatic steps likely to be needed to convince other countries to act should be integral elements of the plan.

Such a plan will inevitably need to be adaptable. Circumstances change; some tasks turn out to be more difficult than expected and new opportunities arise. Hence the plan must be regularly updated and modified as implementation proceeds.

The President and Congress should demand updates every six months on the progress of implementation of the plan, along with any modifications that have been made.

Adequate Resources

The President and Congress should act to ensure that sufficient resources are assigned so that lack of money or qualified personnel are never constraints on efforts that could substantially reduce the risk of nuclear terrorism.

Currently, most programs focused on parts of the problem of reducing the risk of nuclear terrorism are more constrained by bureaucratic and political factors —most importantly, the level of cooperation they have achieved with foreign countries —than they are by lack of funds. A few programs, however, could be significantly strengthened or accelerated with an infusion of additional funds (see the Appendix for a detailed budget analysis and recommendations). And if sustained high-level leadership succeeded in breaking through current constraints, more funding would certainly be needed to carry out the "maximum effort" to keep nuclear weapons and materials out of terrorist hands that the 9/11 Commission recommended.[4]

[3] The unclassified version of this "plan" has almost no content, but does acknowledge that the classified version includes three separate lists of the highest priorities for three different programs, based on each program's own separate methodology for assessing priorities. U.S. Department of Energy, National Nuclear Security Administration, *Report to the United States Congress under Section 3132 of the FY 2005 Defense Authorization Act: Unclassified Executive Summary* (Washington, D.C.: DOE, 2006). That this was because the different programs each had their own priorities and did not come to any agreement on overall priorities is from an interview with a DOE official, November 2005.

[4] National Commission on Terrorist Attacks upon the United States, *The 9/11 Commission Report: Final Report of the National Commission on Terrorist Attacks Upon the United States*, 1st ed. (New York: Norton, 2004; available at http://www.gpoaccess.gov/911/index.html as of 30 December 2006), p. 381.

No one knows for sure how much it would cost to provide high levels of security for all nuclear weapons and weapons-usable nuclear material worldwide. The number of buildings and bunkers worldwide where these materials exist is not known precisely; how many of these require upgrades, and how extensive the needed upgrades might be, depends on the level of security that is set as the goal. (No matter how many security measures have already been taken, additional steps can always be put in place.) In Russia, which has the world's largest and most dispersed nuclear stockpiles, DOE spent nearly $1.2 billion on MPC&A improvements through the end of fiscal year (FY) 2006, and at that time the remaining upgrades planned were expected to cost just under an additional $100 million.[5] In addition, DOE and the Department of Defense together have spent just under $1 billion on upgrading nuclear warhead security in Russia through the end of FY2006.[6] Russia, of course, is paying the costs of providing guard forces, security personnel, and the like, as well as its own investments in security and accounting equipment. While these upgrades do not cover every site, and there are questions about whether they meet the threat in some cases, they provide an order of magnitude. It appears very likely that similar levels of security could be provided for all the nuclear weapon and weapons-usable nuclear material sites and transport operations in the world for an initial capital cost in the range of $3-$6 billion (much of which, of course, should be paid by the countries where these stockpiles exist, or by donor states, rather than putting the entire burden on the United States). That does not include the costs of guard forces, security personnel, regulators, and all the other elements of an effective nuclear security system; and in some cases, the United States may wish to do more (as it has in the former Soviet Union), from re-employing nuclear scientists to paying to destroy stocks of HEU or plutonium, to strengthening countries' ability to interdict nuclear smuggling. But the bottom line is that nuclear security is affordable: a level of security that could greatly reduce the risk of nuclear theft could be achieved for roughly one-percent of annual U.S. defense spending. Lack of money should not constrain the effort to keep these stockpiles out of terrorist hands.

Information and Intelligence to Support Policy

In addition to money, good information on where the greatest risks, opportunities, and obstacles to progress lie will be crucial to preventing nuclear terrorism. The commission on U.S. intelligence on weapons of mass destruction warned that while good intelligence on these matters is critically important, current U.S. intelligence in this area is weak.[7]

Since 9/11, the level of U.S. intelligence focus on trying to figure out what terrorists might be doing related to weapons of mass destruction has increased substantially. But short of success in penetrating a cell that is working on weapons of mass

[5] U.S. Congress, General Accounting Office, *Nuclear Nonproliferation: Progress Made in Improving Security at Russian Nuclear Sites, but the Long-Term Sustainability of U.S.-Funded Security Upgrades Is Uncertain*, GAO-07-404 (Washington, D.C.: GAO, 2007; available at http://www.gao.gov/new.items/d07404.pdf as of 21 May 2007), pp. 12, 16.

[6] U.S. Congress, *Nuclear Nonproliferation: Progress Made in Improving Security at Russian Nuclear Sites, but the Long-Term Sustainability of U.S.-Funded Security Upgrades Is Uncertain*, p. 18.

[7] Commission on the Intelligence Capabilities of the United States Regarding Weapons of Mass Destruction, *Report to the President* (Washington, D.C.: WMD Commission, 2005; available at http://www.wmd.gov/report/ as of 2 January 2007).

destruction, it will always be very difficult to know what individual terrorist groups may be doing in this area.

Other kinds of information that are critical for policy-makers working this problem and that are quite easy to get, have not yet been given priority for collection and assessment (either by intelligence agencies or by policy and implementation agencies). How much are the workers paid at, for example, civilian research reactors with HEU? Is there corruption and theft among those workers? What are the conditions for the guard forces (if any)? What kind of terrorist and criminal activity has there been in the areas where these facilities are located, and what might that suggest about the threats that security at these facilities should be designed to cope with? This kind of information could be critical in assessing risks and in setting priorities. Are particular reactors being used intensively, with plenty of funding, or are they used hardly at all and struggling to find the money to stay open? What do the officials in charge of providing the facilities' funding subsidies think about the possibility of shutting them down? What do the reactor operators think about the possibility of converting to low-enriched uranium? What do national policy-makers and facility operators think about the dangers of nuclear theft and sabotage and the security measures that should be taken to address them? This kind of information could be critical to identifying policy opportunities and obstacles. Comparable kinds of questions can and should be asked about a wide range of other facilities where nuclear weapons and materials exist as well.

Today, no one in the U.S. government (or other governments, as far as I am aware) has been given the task of collecting this type of information in a focused way on facilities with nuclear weapons or weapons-usable nuclear material throughout the world. President Bush and the Congress should direct the intelligence community and the policy and implementation agencies to work together to close that gap.

The U.S. government should immediately develop and implement an interagency plan for collecting and analyzing the information most critical to assessing the risks of nuclear theft at sites throughout the world. In doing so, the U.S. government should be extraordinarily careful not to turn the experts attempting to build nuclear security partnerships with foreign colleagues into spies (or make them perceived to be spies), as that would destroy any hope of building the real partnerships that will be essential to success. In many cases, it may be that collection and analysis should *not* be done by intelligence agencies, but by implementation agencies or even by labs, companies, non-governmental organizations, or universities on contract to the government; these entities can collect open information without the taint of U.S. government "spying."

Perhaps the first priority for information collection and analysis is a prioritized assessment of which facilities worldwide pose the most urgent risks of nuclear theft to be addressed. DOE has developed a list of facilities believed to have weapons-usable nuclear material around the world and is working to integrate what limited information is available about security arrangements and threats at these sites.[8] But to date, this list represents an inventory, not a risk-based assessment of where

[8] Matthew Bunn and Anthony Wier, *Securing the Bomb: An Agenda for Action* (Cambridge, Mass., and Washington, D.C.: Project on Managing the Atom, Harvard University, and Nuclear Threat Initiative, 2004; available at http://www.nti.org/e_research/analysis_cnwmupdate_052404.pdf as of 2 January 2007), p. 103.

the highest priorities for action lie. Such a prioritized global threat assessment should be developed as quickly as possible—identifying not only what is known that gives reason for concern, but what is not known, and using those knowledge gaps to drive efforts to collect additional information to fill them. The record of past U.S. interactions with nuclear facilities should also be documented to the extent possible, so that U.S. officials are aware, in their discussions with facility operators, of what has gone before (DOE has in fact begun to populate the global facilities database with some information gleaned from previous interactions). In this way, judgments of where the highest-priority risks reside can be integrated with judgments concerning where the highest-leverage opportunities may be, or where higher-level political intervention may be needed to make progress.

An Opportunity Not to be Missed

Real and important progress has been made in securing nuclear stockpiles in recent years, particularly in Russia. But there is more to be done there, and the effort in much of the rest of the world is just beginning. Senator Richard Lugar has aptly pointed out that the war on terrorism cannot be considered won until every cache of nuclear weapons and their essential ingredients worldwide is reliably secured from terrorist access.[9] By that standard, victory is still a long way off —but it is within reach. President Bush and the next president, working with President Putin, his successor, and other leaders around the world have an historic opportunity to reduce the risk of nuclear terrorism to a level so low that it would no longer be among the most important threats to U.S. and world security. For the sake of the security of us all, the goal must be no less.

[9] Richard Lugar "NATO's Role in the War on Terrorism," speech before the U.S.-NATO Missions Annual Conference, 19 January 2002,(available at http://www.bits.de/NRANEU/docs/Lugar190102.pdf as of June 17, 2007).

APPENDIX: BUDGET ANALYSIS AND RECOMMENDATIONS*
ANTHONY WIER AND MATTHEW BUNN

The Bush administration's proposed fiscal year (FY) 2008 budget for cooperative threat reduction would reduce the overall funds available and launch few new initiatives or approaches to address the urgent threats posed by inadequately controlled nuclear weapons, materials, and expertise. While sustained high-level leadership to overcome obstacles to cooperation is the most important ingredient for accelerating and strengthening these efforts, additional funds would be needed to carry out the "maximum effort" to keep nuclear weapons and materials to make them out of terrorist hands that the 9/11 Commission recommended.[1]

Overall, if Congress adopted the administration's proposal in its entirety, the cumulative resources available to programs focused on improving controls over nuclear weapons, materials, and expertise would decline to $989 million, 11% below the FY 2006 level (the most recent year for which easy comparisons are available, because of congressional delays in passing appropriations bills to fund most federal programs for FY 2007). Funding for all cooperative threat reduction (which also includes efforts to control chemical and biological threats, along with dismantlement of missiles and submarines) would decrease to $1.3 billion, 9% below the FY 2006 level.

Under the administration's proposal, the State Department's threat reduction efforts would expand to a global focus; the Global Threat Reduction Initiative (GTRI), a Department of Energy (DOE) effort to convert, secure, and clean out civilian facilities with vulnerable nuclear and radiological material, would receive significantly increased resources; and funding for biological threat reduction efforts at the Department of Defense (DOD) would be significantly increased. In contrast, DOE's Global Initiatives for Proliferation Prevention (GIPP) and DOD's Russian Nuclear Warhead Security program would be cut back in comparison to FY 2006 and FY 2007, and there would be no new funding made available for DOD's effort to help Russia destroy its chemical weapons stockpile.[2]

*Reprinted in full from Wier, Anthony and Matthew Bunn, "Funding for U.S. Efforts to Improve Controls Over Nuclear Weapons, Materials, and Expertise Overseas: Recent Developments and Trends." Cambridge, Mass.: Project on Managing the Atom, Belfer Center for Science and International Affairs, February 2007. Anthony Wier is no longer an employee of the Project on Managing the Atom.

[1] National Commission on Terrorist Attacks upon the United States, *The 9/11 Commission Report: Final Report of the National Commission on Terrorist Attacks Upon the United States*, 1st ed. (New York: Norton, 2004; available at http://www.gpoaccess.gov/911/index.html as of 30 December 2006).

[2] These figures are recorded in Anthony Wier, "Interactive Budget Database," in Nuclear Threat Initiative Research Library: Securing the Bomb (Cambridge, Mass., and Washington, D.C.: Project on Managing the Atom, Harvard University, and Nuclear Threat Initiative, 2007; available at http://www.nti.org/e_research/cnwm/overview/funding.asp as of 15 February 2007). Users can use this database to compile custom charts on the cooperative threat reduction goals, agencies, and programs of their choice. For a discussion of which programs are counted in our totals, see Anthony Wier, "Funding Summary," in Nuclear Threat Initiative Research Library: Securing the Bomb (Cambridge, Mass., and Washington, D.C.: Project on Managing the Atom, Harvard University, and Nuclear Threat Initiative, 2006; available at http://www.nti.org/e_research/cnwm/overview/funding.asp as of 7 February 2007). It should be noted that many programs related to controlling

Table A-1: U.S. Appropriations to Improve Controls on Nuclear Weapons, Materials, and Expertise

(Current Dollars, in Millions)

Goal/Program	FY 1992-FY 2007 Real Funding	Department	FY 2006 Final	FY 2007 Estimated [1]	FY 2008 Request	Change From FY 2006	
Total, Improving Controls on Nuclear Weapons, Material, and Expertise			**1,116**	**1,142**	**989**	**-127**	**-11%**
Securing Nuclear Warheads and Materials			564	593	488	-76	-14%
Material Protection, Control, & Accounting (excluding SLD)		Energy	303	353 [2]	282 [3]	-20	-7%
Nuclear Weapons Storage Security - Russia		Defense	129	87	23	-106	-82%
Global Threat Reduction Initiative		Energy	97	115	140	+43	+44%
Nuclear Weapons Transportation Security - Russia		Defense	30	33	38	+8	+26%
International Nuclear Security		Energy	6	6	5	-1	-12%
Interdicting Nuclear Smuggling			214	211	210	-4	-2%
Second Line of Defense (part of MPC&A budget line)		Energy	120	120 [2]	119 [3]	-1	-1%
Export Control and Related Border Security Assistance		State	43	43	41	-2	-4%
WMD Proliferation Prevention		Defense	41	37	38	-3	-6%
International Counterproliferation		Defense	10	11	11	0	+4%
Stabilizing Employment for Nuclear Personnel			100	100	82	-18	-18%
Global Threat Reduction Program [4]		State	52	52	54	+1	+3%
Global Initiatives for Proliferation Prevention		Energy	40	40	20	-19	-49%
Civilian Research and Development Foundation [5]		State	8	8	8	0	0%
Monitoring Stockpiles and Reductions			29	29	28	-1	-4%
HEU Transparency Implementation		Energy	19	19	14	-5	-25%
Warhead and Fissile Material Transparency		Energy	10	10	14	+4	+35%
Ending Further Production			174	174	182	+7	+4%
Elimination of Weapons Grade Plutonium Production		Energy	174	174	182	+7	+4%
Reducing Excess Stockpiles			34	34	0	-34	-100%
Russian Plutonium Disposition [6]		Energy	34	34	0	-34	-100%

Notes

Values may not add due to rounding.

[1] FY 2007 values are estimated pending final allocation decisions by Congress and the Bush administration.

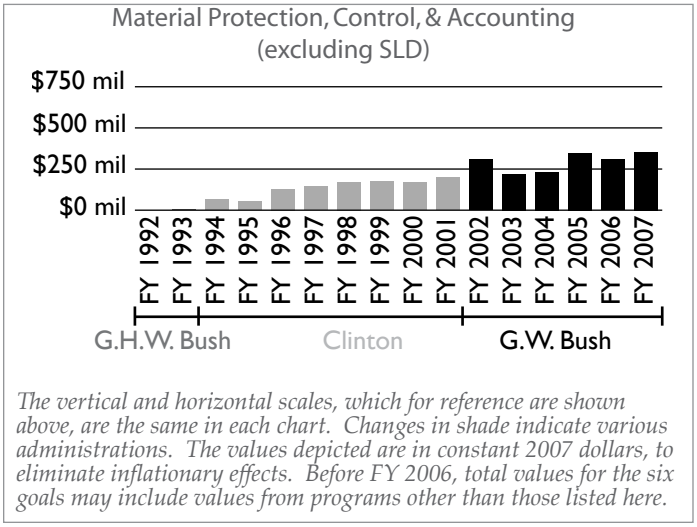
[2] In February 2007, for FY 2007 the administration also requested an additional $49 million for the "core" Material Protection, Control, & Accounting program, as well an additional $14 million for the Global Threat Reduction Initiative. Those requests await action by the Congress.

[3] For FY 2008, the administration requested $30 in supplemental funding to be split in an unspecified way between the "core" Material Protection, Control, & Accounting program and the Second Line of Defense program. For now, we assume all $30 million to be part of the "core" MPC&A program.

[4] In its FY 2008 budget proposal the State Department changed this program's name from the Nonproliferation of Weapons of Mass Destruction Expertise program. A small, but unknown, percentage of the program's resources will go towards its Nuclear Smuggling Outreach Initiatiave.

[5] Amounts for this program are estimated pending further information from the State Department.

[6] The Department of Energy intends to rely on balances from prior-year appropriations to carry out this program in FY 2008.



The vertical and horizontal scales, which for reference are shown above, are the same in each chart. Changes in shade indicate various administrations. The values depicted are in constant 2007 dollars, to eliminate inflationary effects. Before FY 2006, total values for the six goals may include values from programs other than those listed here.

Table A-1 Source: *Anthony Wier, "Interactive Budget Database," in* Nuclear Threat Initiative Research Library: Securing the Bomb *(Cambridge, Mass., and Washington, D.C.: Project on Managing the Atom, Harvard University, and Nuclear Threat Initiative, 2007; available at http://www.nti.org/e_research/cnwm/overview/funding.asp as of 15 February 2007).*

The administration released its FY 2008 budget proposal at the same time Congress and the Bush administration were finalizing funding levels for most of these efforts for FY 2007 (which ends in September 2007), even though over a third of the fiscal year has already passed. House Joint Resolution 20—the bill setting final congressional allocations for FY 2007 for everything the government does except national defense and homeland security (the only two departments for which the 109th Congress managed to pass appropriations bills)—largely adopts, with a few exceptions and alterations, the funding levels under which programs worked in FY 2006.[33] The continuing resolution did provide modest increases over FY 2006 for two DOE threat reduction efforts: GTRI (which got an additional $18.5 million) and the International Material Protection and Cooperation program (which got an additional $50 million). Currently, we estimate that the overall budget available to programs working to control nuclear weapons, materials, and expertise overseas is $1.142 billion in FY 2007, a nominal increase of just over 2% over the FY 2006 level, barely enough to keep up with inflation.

This paper examines the resources U.S. programs working to control nuclear weapons, materials, and expertise overseas will likely have available to them in FY 2007 and 2008 as the result of recent executive and legislative branch decisions. It places those recent decisions in the context of the overall budgetary trends for these programs and steps back to look at budgets for the entire U.S. cooperative threat reduction effort. We conclude the paper with recommendations for additional funding in targeted areas.

Highlights of the FY 2008 Budget Proposal

Taking projected inflation into account, the $989 million requested for programs to improve controls on nuclear warheads, materials, and expertise around the world would represent a real decrease of

expertise or interdicting smuggling cover chemical, biological, and missile technologies as well as nuclear technologies, and hence, by including the full budgets for these programs, we inevitably overestimate somewhat the total budget that is specifically for controlling nuclear warheads, materials, and expertise. Except where noted, figures are taken from the following budget documents: U.S. Department of Defense, Fiscal Year (FY) 2008 Budget Estimates: Former Soviet Union Threat Reduction (Washington, D.C.: U.S. Department of Defense, 2007; available at http://www.dod.mil/comptroller/defbudget/fy2008/budget_justification/index.html as of 7 February 2007); U.S. Department of Energy, FY 2008 Congressional Budget Request: National Nuclear Security Administration—Defense Nuclear Nonproliferation, vol. 1, DOE/CF-014 (Washington, D.C.: DOE, 2007; available at http://www.cfo.doe.gov/budget/08budget/Content/Volumes/Vol_1_NNSA.pdf as of 7 February 2007); U.S. Department of State, Summary and Request: International Affairs Function 150 FY 2008 Budget Request (Washington, D.C.: U.S. Department of State, 2007; available at http://www.state.gov/documents/organization/80151.pdf as of 6 February 2007); U.S. Office of Management and Budget, Fiscal Year 2008 Budget of the United States Government (Washington, D.C.: OMB, 2007; available at http://www.whitehouse.gov/omb/budget/fy2008/ as of 5 February 2007). Other organizations have also created useful analyses of aspects of the FY 2008 budget request related to arms control and nonproliferation. For instance, see Center for Arms Control and Nonproliferation, "Department of Energy Budget Request for FY 2008 - Nuclear Non-Proliferation Highlights" (Washington, D.C.: Center for Arms Control and Nonproliferation; available at http://www.armscontrolcenter.org/archives/002281.php as of 26 February 2007). Also, the Partnership for Global Security (http://www.partnershipforglobalsecurity.org/) will have a summary available, though it was not yet available at the time of this writing.

[3] For the details of the legislation, see U.S. House of Representatives, *Making Further Continuing Appropriations for the Fiscal Year 2007, and for Other Purposes*, 110th Congress, 1st Session, H.J.Res. 20 (2007; available at http://thomas.loc.gov/cgi-bin/bdquery/z?d110:h.j.res.20: as of 15 February 2007).

Figure A-1: Historical U.S. Appropriations to Improve Controls on Nuclear Weapons, Materials, and Expertise

(Constant 2007 Dollars, in Millions)

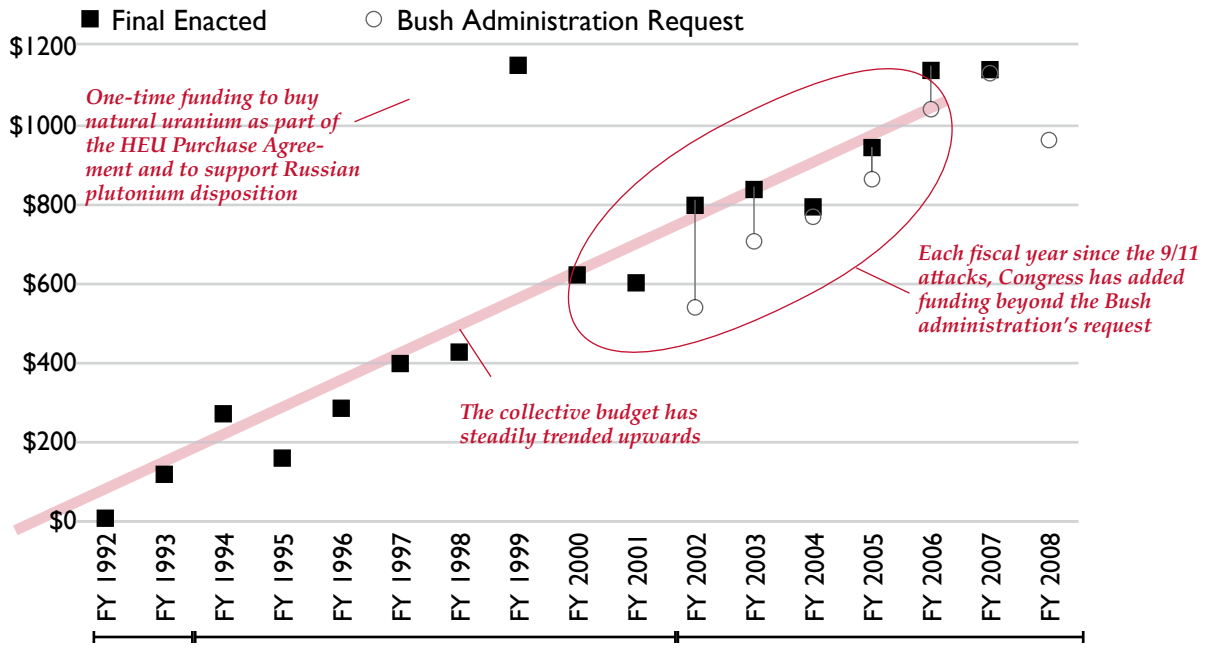


Figure A-1 Source: *"Interactive Budget Database," 2007.*

15% over the FY 2006 level.[44] Such a decrease would buck the trend of steadily increasing annual funding for cooperative programs to improve controls over nuclear weapons, materials, and expertise. In the years since the 9/11 attacks, Congress has repeatedly added funding beyond the administration's initial request for a number of key threat reduction programs; in the subsequent year, the administration has typically followed the Congress' lead, in broad terms (see Figure A-1). While these incremental increases have often not been enough to enable the pace of the U.S. response to match the threat posed by unsecured nuclear weapons, materials, and expertise, the overall resource trend has been undeniably upward—and it is clearly not the case that Congressional budget constraints have limited the administration's ability to carry out these programs faster.

Several items of note stand out in the FY 2008 budget proposal.

- As the effort to upgrade security for nuclear stockpiles in Russia nears its December 2008 target for completion, DOE is proposing to reduce new funding for the "core" Material Protection, Control, and Accounting (MPC&A) program—that is, excluding the anti-smuggling Second Line of Defense program, which the administration counts under the same budget line but that we track separately to indicate its separate mission. As detailed in Table A-2, MPC&A would go from approximately $303 million in new resources in FY 2006 to roughly $282 million in FY 2008, a 7% reduction. DOE submitted

[4] To adjust for inflation, we have used the Total Composite Outlay Deflator from Table 10.1, in the Historical Tables section of U.S. Office of Management and Budget, *FY 2008 Budget of the U.S. Government*.

Table A-2: Enacted and Proposed Appropriations for the Department of Energy's Nuclear Materials Protection and Cooperation Program, FY 2006-2008

(Current Dollars, in Millions)

Program/Subprogram	FY 2006 Final	FY 2007 Estimated [1]	FY 2008 Request	Change From FY 2006	
Total, Nuclear Materials Protection and Cooperation	**422.730**	**472.730**	**401.771**	**-20.959**	**-5%**
Material Protection, Control, & Accounting "core" program	302.776	352.776	282.440	-50.336	-17%
Navy Complex	16.966		13.390	-3.576	-21%
Strategic Rocket Forces/12th Main Directorate	107.761		91.449	-16.312	-15%
Rosatom Weapons Complex	89.274		60.114	-29.160	-33%
Civilian Nuclear Sites	27.341		22.188	-5.153	-19%
Material Consolidation and Conversion	21.583		19.667	-1.916	-9%
National Programs and Sustainability	39.851		45.632	+5.781	+15%
Unallocated Supplemental Request		[49.000] [2]	30.000 [3]	n/a	n/a
Second Line of Defense	119.954	119.954	119.331	-0.623	-1%

Notes

[1] FY 2007 values are estimated pending final allocation decisions by Congress and the Bush administration.

[2] In February 2007, for FY 2007 the administration requested an additional $49 million for the "core" Material Protection, Control, & Accounting program. That request awaits action by the Congress.

[3] For FY 2008, the administration requested $30 in supplemental funding for the "core" Material Protection, Control, & Accounting program

Table A-2 Source: *U.S. Department of Energy,* FY 2008 Congressional Budget Request: National Nuclear Security Administration--Defense Nuclear Nonproliferation, *vol. 1, DOE/CF-014 (Washington, D.C.: DOE, 2007; available at http://www.cfo.doe.gov/budget/08budget/Content/Volumes/Vol_1_NNSA.pdf as of 7 February 2007), p. 471.*

a regular request of $252 million for the "core" program, but the administration is also requesting $30 million as part of its request for emergency supplemental appropriations to carry out the "Global War on Terror." DOE attributes the bulk of the decrease to the completion of comprehensive security upgrades at five nuclear warhead storage sites overseen by Russia's Strategic Rocket Forces.[55]

- DOE is requesting an FY 2008 budget of almost $140 million for the Global Threat Reduction Initiative (GTRI). Just under $120 million of that request would come as a regular appropriation, while the other $20 million is being sought as part of the administration's emergency supplemental request for FY 2008. GTRI had a budget of approximately $97 million in FY 2006, making the proposed FY 2008 total a 44% jump. As shown in Table A-3, most of the increase would support the effort to safely transport and store proliferation-sensitive spent fuel in Kazakhstan, while some would also go to enhancing work to return Soviet-origin highly enriched uranium (HEU) fuel Russia for safekeeping and ultimate conversion to low enriched uranium.

- Under the proposal, DOD's Nuclear Warhead Security-Russia program would see its budget drop to just under $23 million, compared to $87 million in FY 2007 and $129 million in FY 2006. DOD believes that site security

[5] U.S. Department of Energy, FY 2008 Defense Nuclear Nonproliferation Budget Request, p. 482.

Table A-3: Enacted and Proposed Appropriations for the Department of Energy's Global Threat Reduction Initiative, FY 2006-2008

(Current Dollars, in Millions)

Program/Subprogram	FY 2006 Final	FY 2007 Estimated[1]	FY 2008 Request	Change From FY 2006	
Total, Global Threat Reduction Initiative	**96.995**	**115.495**	**139.626**	**+42.631**	**-5%**
Reduced Enrichment for Research and Test Reactors (RERTR)	24.732		31.190	+6.458	+26%
Russian Research Reactor Fuel Return (RRRFR)	14.703		31.046	+16.343	+111%
U.S. Foreign Research Reactor Spent Nuclear Fuel (FRRSNF)	8.100		4.211	-3.889	-48%
Emerging Threats and Gap Materials	5.000		1.721	-3.279	-66%
U.S. Radiological Threat Reduction (USRTR)	12.566		13.228	+0.662	+6%
Kazakhstan (BN-350 Reactor) Spent Fuel	8.000		31.722	+23.722	+296%
Global Research Reactor Security	0.000		0.500	+0.500	n/a
International Radiological Threat Reduction (IRTR)	23.894		6.008	-17.886	-75%
Unallocated Supplemental Funding [2]	n/a	[14.000]	20.000	n/a	n/a

Notes

[1] FY 2007 value is estimated pending final allocation decisions by Congress and the Bush administration.

[2] In February 2007, the administration requested $14 million for FY 2007 and $20 million for FY 2008 for the Global Threat Reduction Initiative. Congress has yet to act on those requests.

Table A-3 Source: *DOE,* FY 2008 Congressional Budget Request*, p. 513.*

enhancements will be largely completed by FY 2008, reducing the need for additional funds. The program received $44 million in supplemental FY 2006 funding to accelerate security upgrades.[66]

- In contrast, DOD's Nuclear Warhead Transportation Security program would receive an increase of almost $5 million over FY 2007, for a total of $38 million. The additional funds would allow the program to procure up to four extra railcars to transport Russian warheads securely to storage or dismantlement facilities.

- The program to dispose of excess Russian weapons plutonium would receive no new money in FY 2008; it had received $34 million in new funding in FY 2006. The program has been relying on $225 million in funds provided in FY 1999, and is not requesting additional funds, as it had in several past years, to support ongoing operations.

- DOE's Global Initiatives for Proliferation Prevention would see a significant decrease in annual funding under the FY 2008 budget proposal. The program is requesting just over $20 million, in nominal terms almost half of its almost $40 million budget for FY 2006. Less funding is being sought because of the demise of the Nuclear Cities Initiative, which resulted from U.S. and Russian failure, in September 2006, to renew the NCI implementing agreement.

[6] For the explanation, see U.S. Department of Defense, *FY 2008 CTR Budget Justification*, p. 924.

Figure A-2: Components of Departments of Energy, State, and Defense FY2008 Budget Requests Devoted to Cooperative Threat Reduction Programs

(each full box represents $1 billion)

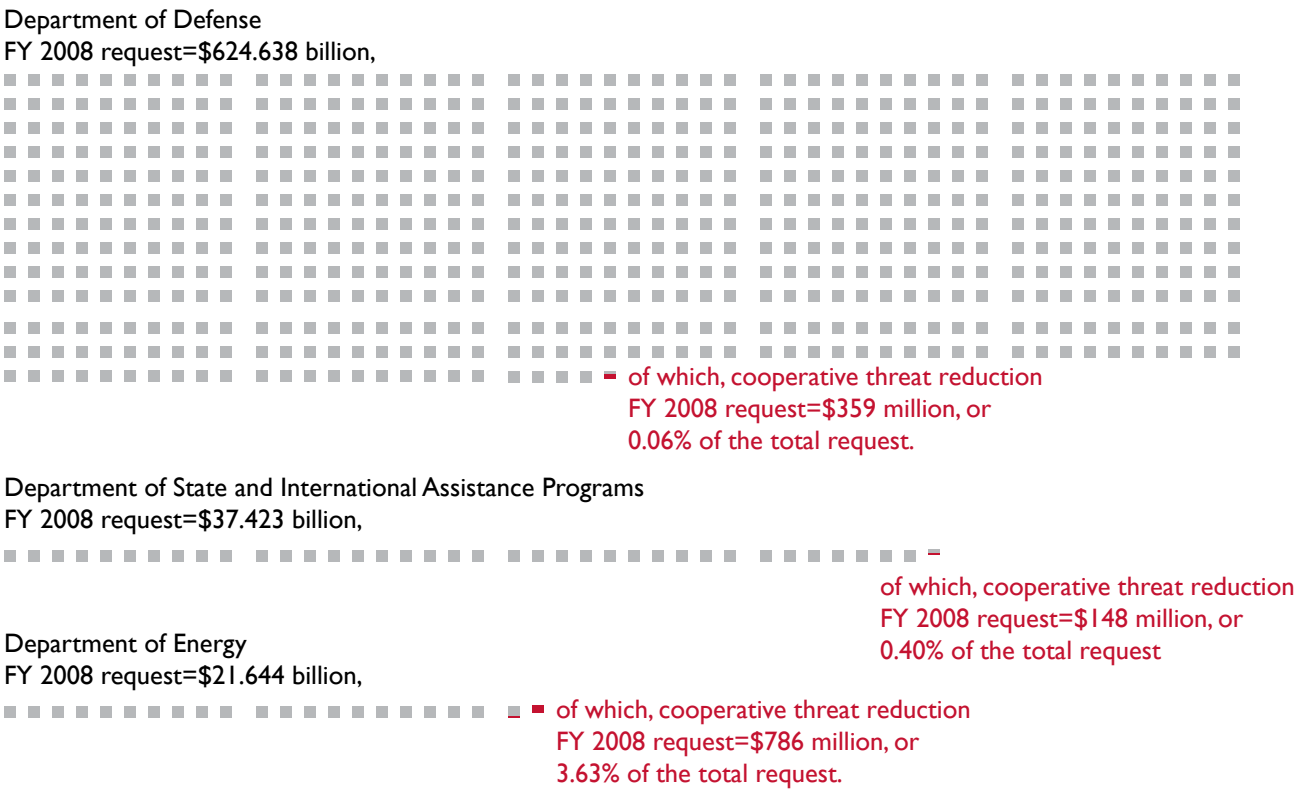


Figure A-2 Source: *Department budget requests from Table 5.2 in U.S. Office of Management and Budget, "Historical Tables,"* Fiscal Year 2008 Budget of the United States Government *(Washington, D.C.: OMB, 2007; available at http://www.whitehouse.gov/omb/budget/fy2008/ as of 5 February 2007). Department totals include OMB estimates of supplemental funding requests for FY 2008.*

The State Department's FY 2008 request proposes to change the name and the scope of a budget item that used to be known as the Nonproliferation of WMD Expertise program. Now named the Global Threat Reduction Program, the effort is designed to reduce risks of proliferation of nuclear, chemical, and biological expertise and materials around the world. The new global focus, with little increase in requested resources, appears likely to lead to cutbacks in funding for the International Science and Technology Centers in the former Soviet Union, U.S. funding for which comes from this program. Little information has been released as to what methods this effort would use, what targets it would aim for, how much it would ultimately cost, or how it will relate to other programs, though it appears that the primary focus, at least initially, would be on expertise and on biological materials. The effort includes, however, a Nuclear Security Outreach Initiative that has begun carrying out assessments of nuclear security improvement needs (ranging from physical protection to anti-smuggling measures) in several countries.

Several other programs would see slight changes in their budgets, as noted in Table A-1.

While this paper examines the cumulative resources available for these programs

throughout the government, it is important to understand that at no point in the annual budget process does the government itself consider the budgets for all of these programs collectively. The Departments of Energy, Defense, and State each follow separate tracks toward their final budget numbers. Budget tradeoffs are generally made within each department, and each budget is set by separate appropriations subcommittees in both the House and Senate. In the FY 2008 budget submission, DOD programs are responsible for most of the cumulative reduction in resources from FY 2006. In comparison to our estimate for FY 2007, DOE programs look like the biggest losers, but those reductions come from resource levels that are higher in FY 2007 than they were in FY 2006. The resources available to programs at the State Department would be little changed by the proposal for FY 2008.

It is important to understand how small the budgets for cooperative threat reduction programs are in comparison to the departments that house them, as Figure A-2 shows. Without serious effort by departmental leadership, it would be—indeed, it has been—very easy for these programs to get lost in the shuffle of these departments' other concerns and decisions. At the same time, the targeted additional resources recommended in this paper would not dramatically alter these agencies' budgetary bottom lines, a fact that should make such recommendations easier to swallow. What is more, with the aftermath of the 9/11 attacks as a guide, the additional resources recommended below would certainly pale in comparison to the growth in these departments' budgets that would follow a terrorist attack with a nuclear, chemical, or biological weapon.

Review of FY 2007 Budget Outcomes

A tumultuous budget process for FY 2007 has tentatively resulted in a slight cumulative increase over the previous year in the resources available to programs aimed at improving controls over nuclear weapons, materials, and expertise overseas. As noted above, House and Senate leaders only finalized negotiations on funding legislation in late January 2007. The 109th Congress had failed to complete nine of the eleven annual spending bills before it finished work after the November 2006 congressional election (only the defense and homeland security funding bills were completed). The outgoing 109th Congress instead provided provisional funding through February 15, 2007. As a result, Congress and the president had to complete work on the legislation early in the 110th Congress, lest most of the federal government's activities be interrupted.

It is important to note that, while Congress largely adopted the FY 2006 budget levels in the bill funding the remainder of FY 2007, it also provided the administration with leeway in allocating budgets among programs within a given appropriation account. (All of the DOE nonproliferation programs, for example, are in a single appropriation account.) As a result, the estimates provided here for FY 2007 for individual threat reduction programs at the Departments of Energy and State—which use FY 2006 as their guide—are tentative, pending final executive branch decisions.

In addition, at the same time the administration submitted its budget proposal and supplemental request for FY 2008, it also transmitted a request for supplemental funds for FY 2007. The request included $49 million in additional funds for the line that funds both the MPC&A program and

the Second Line of Defense effort, and $20 million in additional funds for GTRI.

With these warnings in mind, as of February 2007 the estimated appropriation for programs for improving controls over nuclear warheads, materials, and expertise overseas is $1.149 billion for FY 2007, an increase of $26 million over FY 2006 and some $80 million compared to the administration's original FY 2007 request. If one accounts for estimates of the rising costs of domestic goods and services, that cumulative total represents virtually no real increase in resources over the previous year.

As with the FY 2008 budget proposal, changes in the overall level are spread unevenly among several programs.

In the final FY 2007 funding bill, House and Senate appropriators made a special point of adding $50 million beyond the FY 2006 level to the Material Protection, Control, and Accounting (MPC&A) budget line (for most programs in the government, the bill merely adopted the FY 2006 level without comment). DOE plans to spend these funds on the MPC&A "core" program (rather than the Second Line of Defense effort funded from the same budget line), raising the MPC&A program's budget for FY 2007 to $353 million, almost $64 million more than the administration had originally requested for FY 2007. DOE officials report that the additional funds will pay for secure trucks to transport weapons-usable nuclear material and for upgrades at Strategic Rocket Forces warhead sites that Russia opened for cooperation after the FY 2007 budget request was prepared, as well as easing pressures created by increases in labor and construction costs in Russia since those budget decisions were made. The Second Line of Defense program will have an estimated $120 million, the same as in FY 2006. As noted above, the emergency supplemental request for FY 2007 includes an additional $49 million for this budget line. DOE officials indicate that these funds would also go to the MPC&A effort, paying for upgrades at key buildings Russia only recently made available for cooperation at major Russian nuclear weapons facilities, and for additional upgrades outside the Soviet Union.[77]

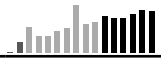
The 110th Congress also specifically added $18.5 million over the FY 2006 level for the Global Threat Reduction Initiative, meaning the effort will have just over $115 million available for FY 2007. In its initial FY 2007 budget request the administration sought slightly under $107 million for the program, while the House, in the 109th Congress, had initially voted to provide nearly $148 million for FY 2007.

In the stand-alone funding bill for the Department of Defense (DOD), which the 109th Congress passed and the president signed into law before the start of FY 2007, Congress adopted the administration's funding request for DOD cooperative threat reduction programs. In early 2006, Congress provided $44.5 million in supplemental FY 2006 funding for DOD's Cooperative Threat Reduction program, in response to an administration request for additional funds for the Nuclear Weapons Storage Security program, which is working with the Russian Ministry of Defense to enhance security at Russian nuclear weapons storage sites. As a result of the supplemental, the $87 million provided for FY 2007 (at the request of the administration) looks like a reduction, when in fact that amount is higher than the $84 million the program originally had received in FY 2006. The closely linked DOD program for Nuclear Weapons Transportation Security in Russia received $33 million for FY 2007, as opposed to $30 million in FY 2006.

[7] Interview with DOE official, February 2007.

TABLE A-4: U.S. APPROPRIATIONS FOR COOPERATIVE THREAT REDUCTION, BY DEPARTMENT

(Current Dollars, in Millions)

Department	FY 1992-FY 2007 Real Funding	FY 2006 Final	FY 2007 Estimated [1]	FY 2008 Request	Change From FY 2006	
Total, Cooperative Threat Reduction		**1,426**	**1,415**	**1,293**	**-133**	**-9%**
Department of Energy		809	877 [2]	786	-23	-3%
Department of Defense		462	383	359	-103	-22%
Department of State		155	155	148	-7	-5%

Notes

Values may not add due to rounding. The vertical and horizontal scales are the same in each chart. Changes in shade indicate various administrations. The values depicted are in constant 2007 dollars, to eliminate inflationary effects.

[1] FY 2007 values are estimated pending final allocation decisions by Congress and the Bush administration.

[2] In February 2007, for FY 2007 the administration also requested an additional $49 million to be split between the Material Protection, Control, & Accounting program and the Second Line of Defense program, as well an additional $14 million for the Global Threat Reduction Initiative. That request has yet to be acted upon, and is not included in this total.

Table A-4 Source: *"Interactive Budget Database," 2007.*

DOD's WMD Proliferation Prevention program, another program working to enhance other countries' capacity to interdict nuclear and other weapons of mass destruction smuggling, has a budget of just over $37 million in FY 2007, as opposed to a FY 2006 budget of $41 million.

Congress chose not to add FY 2007 funding for any other programs from the Departments of Energy and State, though as noted above, the executive branch will enjoy unusual leeway in allocating funding among programs within appropriations accounts. As a result, the final funding levels may differ from estimates based on the FY 2006 level. If the administration chooses to exercise its option to increase some programs, other programs will have to be cut—even though some programs are already facing budgets lower than they had planned for. For example, excluding the amounts Congress has required be spent on the MPC&A and GTRI efforts, DOE will have broad discretion to allocate nearly $1.1 billion in the Defense Nuclear Nonproliferation account. Unfortunately for DOE, in its initial FY 2007 request it had sought over $1.2 billion for the programs other than MPC&A and GTRI that the Defense Nuclear Nonproliferation account funds.

Besides the resource additions or subtractions resulting from the unusual FY 2007 appropriations process, the delays and uncertainty of the FY 2007 process have complicated the work being done to control nuclear weapons, materials, and expertise. So long as Congress and the president had yet to complete final funding legislation, programs could only spend a proportional amount of the lowest possible level at which funding might have been approved, namely, the lowest of the FY 2006 level, the level approved by the full House, and, when it managed to do so, the level approved by the full Senate. This inhibited contracting, overseas travel, and other program execution. At

the same time, budget planning for the next fiscal year in the executive branch is finalized in the first months of the preceding fiscal year. Delays in the FY 2007 process therefore upended planning for FY 2008 and beyond, because programs did not have a clear understanding of the resources they would have available to carry out their work.

Total Cooperative Threat Reduction Funding

As noted earlier, annual funding for cooperative programs working to reduce the threat of nuclear terrorism has trended mostly upward. That funding trend has driven overall cooperative threat reduction funding upward—that is, the budgets that include not only efforts to improve controls over nuclear weapons, materials, and expertise, but also efforts to control biological and chemical threats and to dismanle missiles, bombers, and submarines.[8] When funding for programs mostly focused on the nuclear threat are removed, the recent annual funding trend for these other cooperative threat reduction efforts has been downward, particularly when inflation in the costs of goods and services is taken into account.

Overall, from FY 1992—when funding for cooperative threat reduction efforts first got underway—through FY 2007, the U.S. Government has budgeted nearly $13.3 billion in nominal dollars for cooperative threat reduction programs. In real terms, that would amount to over $15.5 billion in 2007 dollars.

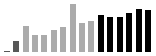
For FY 2008, the administration has requested a total cooperative threat reduction budget of $1.293 billion, as shown in Table A-4. That would represent an 8% decrease from the previous year's estimated level (over 10% if one accounts for inflation). Beyond the key movers discussed among nuclear-oriented programs, the biggest proposed changes would come in the following programs:

DOD is not requesting any more funding for the Chemical Weapons Destruction Facility in Russia. In FY 2007 DOD received the last $43 million in funding that it intends to spend on chemical weapons destruction in the former Soviet Union. The job of destroying chemical weapons left over from the Soviet stockpile has received approximately $1.1 billion since the Nunn-Lugar program began (about $1.3 billion in 2007 dollars).

[8] By "cooperative threat reduction," we include not only the original program at the Department of Defense often referred to as the Cooperative Threat Reduction program, or the Nunn-Lugar program, after the senators who launched the effort in 1991, but also programs funded by the Departments of Energy and State working towards the same goal. Calculating total funding for these efforts involves a large number of choices about what programs to include and not to include; as a result, numbers from different sources are sometimes quite different. We include a number of small programs that are sometimes left out in the administration's accountings of threat reduction spending, but at the same time, we do not include as threat reduction DOE's spending on eliminating its own excess stockpiles of HEU and plutonium (an effort included in DOE's nonproliferation budget, and sometimes included in overall threat reduction tallies). To be consistent, if U.S. efforts to control and reduce U.S. stockpiles were to be included, then U.S. expenditures on dismantling U.S. missiles and submarines, securing U.S. warheads and materials, destroying U.S. chemical weapons, and the like should also be included in the total. For more detail on what is included in our totals, see Anthony Wier, "Funding Summary," in *Nuclear Threat Initiative Research Library: Securing the Bomb* (Cambridge, Mass., and Washington, D.C.: Project on Managing the Atom, Harvard University, and Nuclear Threat Initiative, 2006; available at http://www.nti.org/e_research/cnwm/overview/funding.asp as of 7 February 2007). We use a broad definition of cooperative threat reduction that includes some funds the Bush administration does not count in its contributions towards the Group of Eight industrial nations' Global Partnership against the Spread of Weapons of Mass Destruction.

Table A-5: U.S. Appropriations for Cooperative Threat Reduction

(Current Dollars, in Millions)

Goal/Program	FY 1992-FY 2007 Real Funding	Department	FY 2006 Final	FY 2007 Estimated[1]	FY 2008 Request	Change From FY 2006	
Total, Cooperative Threat Reduction			**1,426**	**1,415**	**1,293**	**-133**	**-9%**
Improve Controls over Nuclear Weapons, Material, & Expertise			1,116	1,142	989	-127	-11%
Other Threat Reduction			310	273	304	-6	-2%
Biological Threat Reduction Program - Former Soviet Union[2]		Defense	70	68	144	+75	+107%
Strategic Offensive Arms Elimination - Russia		Defense	50	76	78	+28	+57%
Chemical Weapons Destruction Facility - Russia		Defense	109	43	0	-109	-100%
Other Threat Reduction/Administrative Support		Defense	15	18	19	+4	+30%
Defense-Military Contacts		Defense	8	8	8	0	0%
Strategic Nuclear Arms Elimination - Ukraine		Defense	1	1	0	-1	-100%
Arctic Military Environmental Cooperation		Defense	>0	1	0	-0	-100%
Nonproliferation and Disarmament Fund		State	37	37	30	-7	-19%
Georgia Border Security and Law Enforcement Assistance[3]		State	15	15	15	0	0%
International Nonproliferation Export Control Cooperation		Energy	6	6	10	+4	+64%

Notes

Values may not add due to rounding. The vertical and horizontal scales are the same in each chart. Changes in shade indicate various administrations. The values depicted are in constant 2007 dollars, to eliminate inflationary effects. Before FY 2006, total values for goals may include values from programs other than those listed here.

[1] FY 2007 values for Department of Energy and State programs are estimated pending final allocation decisions by Congress and the Bush administration.

[2] In the explanation of the FY 2008 budget request, DOD noted this new name for the program that had been known as the Biological Weapons Proliferation Prevention program.

[3] All values for this program are estimates based on prior year appropriations, pending further information from the State Department.

Table A-5 Source: *"Interactive Budget Database," 2007.*

Instead, DOD is proposing to direct significant resources in FY 2008 to its Biological Threat Reduction program in the former Soviet Union, which works to consolidate and secure dangerous pathogens and improve on the safety and security practices of biological facilities. The proposed budget of $144 million for FY 2008 would double the amount of resources available for the program, even though DOD admits that its "effort in Russia is very limited due to Russian aversion to cooperate on biological threat reduction."[9]

[9] U.S. Department of Defense, *FY 2008 CTR Budget Justification*, p. 915.

The State Department's Nonproliferation and Disarmament Fund, which supports *ad hoc* operations to fulfill a nonproliferation or disarmament mission for which other U.S. Government funding is not available, would see its annual replenishment fall from over $37 million in FY 2006 to $30 million in FY 2008.

As with programs focused on the nuclear threat, several other cooperative threat reduction programs would see slight changes in their FY 2008 budget, as shown in Table A-5.

Conclusions and Recommendations

This appemdix has focused on the resources the administration's budget proposal would make available for threat reduction. But what one is buying is usually more important than what one is paying. Resource levels only serve as proxies for how much work might be attempted in the coming year; they offer little information on the real progress achieved as a result of those resources. The main text of this report focuses on the results achieved, and gaps remaining.

After over a decade of experience, the overall record of programs working to improve controls over nuclear weapons, materials, and expertise overseas—and of cooperative threat reduction in general—is clear: the resources provided have bought dramatic results, at a price dramatically lower than other national security and foreign policy programs. As a whole, these programs have dramatically reduced the nuclear, chemical, biological, and missile threat facing the United States. Targeted, well-crafted additions to the resources already available promise to provide even greater contributions to the national security of the United States.

To seize all of the opportunities that are already open for improving security for nuclear stockpiles or interdicting nuclear smuggling would require additional investments in several programs in both FY 2007 and FY 2008:

GTRI. GTRI urgently needs additional funds for several efforts: providing incentives to convince vulnerable sites to convert from HEU to LEU and allow their HEU stocks to be removed; carrying out security upgrades at HEU-fueled research reactors (currently budgeted for only $0.5 million in FY 2008, far less than the amount needed to carry out substantial upgrades at a single site); covering a broader segment of the potentially dangerous "gap" HEU and plutonium stocks around the world not covered by existing programs (currently budgeted for only $1.7 million in FY 2008); and addressing potentially deadly radiological sources (where the FY 2008 request is just over one quarter of the resources available in FY 2006, and crucial work to secure especially high-risk sources, such as Russian radiothermoelectric generators (RTGs) is being slowed by lack of funds). Congress should consider a supplemental appropriation for GTRI in the range of $50 million for FY 2007 (rather than the $14 million the administration has requested), and a total appropriation for FY 2008 in the range of $180 to $200 million (rather than the $139.6 million the administration has requested).

Nuclear forensics. An improved ability to determine where nuclear material came from—either after a seizure or after a terrorist nuclear event—could help deter hostile states from transferring nuclear material to terrorists. The administration has requested $12 million for nuclear forensics research and development in FY 2008, but that is only enough to support a very modest research effort (our charts do not reflect this funding because, even though this effort is critical for the overall effort of preventing nuclear terrorism, it is not a task that directly improves controls over nuclear weapons and materials overseas). Congress should consider an appropriation in the range of $50 million for FY 2008, and should also examine the possibility of supplemental funding in FY 2007 to kick-start current efforts.

MPC&A. As noted earlier, both the $50 million increase for FY 2007 that Congress granted the MPC&A program in the continuing resolution and the administration's $49 million supplemental FY 2007 request for this effort are urgently needed. These funds will make it possible to seize

opportunities to secure vulnerable nuclear material transports, upgrade security for additional Russian nuclear warhead sites, improve security measures at key buildings in Russia's nuclear weapons complex, and continue needed nuclear security upgrades outside of the former Soviet Union. Still more funds may be needed, for several reasons. First, prices for both labor and materials in Russia continue to increase—more quickly in some cases than envisioned in budget plans. Second, as this effort moves toward its 2008 target for completing upgrades in Russia and plans for the transition to Russia and the other former Soviet states maintaining high levels of nuclear security on their own, additional funds are needed to work with these states to ensure that effective security systems will be sustained (especially in the case of nuclear warhead sites, where less effort has so far been made in preparing for this transition). Third, more resources are likely to be required to improve regulation of nuclear security and accounting (a critically important factor, as most nuclear managers will only invest in the security measures the government requires them to take) and to strengthen security culture. Fourth, there are many aspects of security only the recipients of international assistance can control, from providing effective guard forces to combating the extensive corruption and insider theft that plagues these nations and their nuclear establishments; while these states must pay for these matters themselves, more funds may be needed to convince them, and help them, to do so. Fifth, as additional opportunities open up in states such as China and India (where progress may finally be possible as broader civilian nuclear cooperation is established), more money will be needed to pursue them. Congress should ask the administration whether additional funds in FY 2007 and FY 2008 would make it possible to seize additional opportunities to reduce nuclear terrorism risks.

UN Security Council Resolution (UNSCR) 1540 implementation. UNSCR 1540 legally requires every country in the world to provide "appropriate effective" security and accounting for any stocks of nuclear, chemical, or biological weapons or the materials to make them they may have; appropriate effective export controls; appropriate effective border and transshipment controls; and more. This resolution was designed to be a key element in the effort to keep weapons of mass destruction out of the hands of terrorists, yet efforts to follow through are only beginning, and at an absurdly small scale. The United States should be doing much more to make use of this new nonproliferation tool, working with leading states and international organizations on several central aspects of UNSCR 1540 implementation: defining the essential elements of effective systems in each of these areas; assessing how well states are implementing those essential elements; and pressuring (and helping) states to meet these critical new legal obligations. The A.Q. Khan network, which operated in dozens of countries around the world, demonstrated how critical it is that all states put such controls in place. Congress should consider providing $50 million in supplemental funding in FY 2007 and a larger sum in FY 2008 to finance State Department and DOE efforts to work with countries around the world to ensure that these critical obligations are met.

International Atomic Energy Agency (IAEA) Office of Nuclear Security. The IAEA has a critical role to play in preventing nuclear terrorism, providing international guidelines, training, and peer reviews, and managing the international database of nuclear smuggling incidents. Many countries that may be suspicious of U.S. assistance are willing to work with the IAEA. Yet all of the IAEA's efforts are constrained by chronically

short budgets, most of which can be spent only on particular projects designated by donor states, leaving little available to respond quickly to events. Congress should consider providing an additional $10 million in supplemental funding for the U.S. contribution to the IAEA Office of Nuclear Security in FY 2007, and comparable increases in FY 2008. Congress should give the IAEA the latitude to spend these funds where they are most needed in the fight against nuclear terrorism, but should consider tying the funds to improved metrics of progress and performance in meeting them.

Expanded blend-down of HEU. The current agreement under which the United States purchases LEU blended from 30 tons of Russian weapons HEU each year, for use as commercial reactor fuel, will come to an end in 2013. At that time, Russia will still have hundreds of tons of HEU beyond any plausible military need (though not all of it may be 90% enriched, as the material currently being blended is). Congress should consider providing a conditional appropriation in the range of $200 million to support providing incentives to convince Russia to blend down large quantities of additional HEU—both to achieve the national security benefit of destroying this potential bomb material, and to ease the pressure on nuclear fuel markets.

In addition to these additional appropriations specifically targeted on reducing threats of nuclear terrorism, there are also broader threat reduction efforts that appear to require additional funds:

Contributions to an International Nuclear Fuel Bank. Uranium enrichment and spent fuel reprocessing are the key technologies that make it possible to produce material for nuclear weapons. To help convince countries pursuing nuclear energy programs that they can rely on foreign supplies of fuel and do not need to establish their own enrichment and reprocessing capabilities, a variety of international fuel supply assurance proposals are being pursued. In particular, the IAEA is working to establish a fuel bank upon which countries that forgo enrichment or reprocessing technology could call in the event their nuclear fuel supplies are cut off. The Nuclear Threat Initiative, backed by Warren Buffett, has offered $50 million toward the establishment of such a bank, if that $50 million is matched by $100 million from governments or other sources within the next two years. Congress should consider providing a conditional appropriation of $50 million to support a fuel bank, as proposed in legislation sponsored by Rep. Tom Lantos, once the IAEA and other fuel suppliers work out arrangements for the bank and other countries contribute $50 million toward creating the bank.

Chemical weapons destruction. The president's budget proposal includes no additional funds for destroying Russia's vast chemical weapons stockpile. Although prior-year funding represents all of the funds the United States had planned to provide for the Shchuch'ye nerve gas destruction facility, cost estimates for the facility have increased, and it remains important to complete a facility capable of carrying out the full mission; cutting off funding now could result in an expensive white elephant that never in fact destroys the deadly chemical weapons at Shchuch'ye.

Global control of nuclear, chemical, and biological expertise. As noted earlier, the State Department's efforts to expand its threat reduction programs globally without a major increase in resources is resulting in cutbacks in science support in the former Soviet Union. Similarly, as noted earlier, DOE's expertise-related efforts are being cut back with the demise of the Nuclear Cities Initiative. Congress

should consider a larger investment in controlling critical information and expertise related to nuclear, chemical, and biological weapons worldwide. At the same time it should closely examine the true impact these programs are able to have on the threat that expertise will proliferate.

In short, while much has been accomplished in securing and reducing nuclear stockpiles around the world and cooperatively reducing other mass-destruction threats, much more remains to be done. Modest additional investments in FY 2007 and FY 2008 could significantly contribute to reducing the risk of nuclear terrorism.

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ABOUT THE AUTHOR

Matthew Bunn is the Senior Research Associate in the Project on Managing the Atom at Harvard University's John F. Kennedy School of Government. His current research interests include nuclear theft and terrorism; nuclear proliferation and measures to control it; and the future of nuclear energy and its fuel cycle. He is the winner of the American Physical Society's Joseph A. Burton Forum Award for "*outstanding contributions in helping to formulate policies to decrease the risks of theft of nuclear weapons and nuclear materials*" and is an elected Fellow of the American Association for the Advancement of Science.

From 1994 to 1996, Bunn served as an adviser to the White House Office of Science and Technology Policy, where he took part in a wide range of U.S.-Russian negotiations relating to security, monitoring, and disposition of weapons-usable nuclear materials, and directed a secret study of security for nuclear stockpiles for President Clinton. The author or co-author of some 18 books or technical reports and dozens of articles, Bunn directed the study *Management and Disposition of Excess Weapons Plutonium*, by the U.S. National Academy of Sciences' Committee on International Security and Arms Control, and served as editor of the journal *Arms Control Today*.

ACKNOWLEDGEMENTS

This report was sponsored by the Nuclear Threat Initiative. Additional funding was provided by the John D. and Catherine T. MacArthur Foundation and the Ploughshares Fund. I would like to thank the many officials of the U.S. and Russian governments and international organizations, as well as experts at U.S. and Russian nuclear facilities, who gave generously of their time in discussions of these critical issues. These officials and experts prefer to remain anonymous. I am particularly grateful to Anthony Wier, my colleague and coauthor for many years, who played a key role in shaping this report in its early stages, before his departure, and useful advice later. Micah Zenko provided outstanding research assistance, advice, and course corrections throughout the effort. Neal Doyle ably laid out the report and designed the figures. Patricia McLaughlin provided constant support throughout, offering a sharp eye for errors and infelicities. I am grateful to a wide range of colleagues who provided helpful comments, ideas, and suggestions, particularly including Charles Curtis, Laura Holgate, Brooke Anderson, Lisa Cutler, and Cathy Gwin at the Nuclear Threat Initiative; Graham T. Allison, John P. Holdren, Martin Malin, and Tom Bielefeld at Harvard University; Frank von Hippel at Princeton University; and William Potter at the Monterey Institute for International Studies.

All responsibility for remaining errors and misjudgments, of course, is my own.

ABOUT THE PROJECT ON MANAGING THE ATOM

The Project on Managing the Atom (MTA) at Harvard University brings together an international and interdisciplinary group of experts and government officials to address key issues affecting the future of nuclear weapons, nuclear nonproliferation, and nuclear energy, particularly where these futures intersect.

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- Martin B. Malin, Executive Director, Project on Managing the Atom
- Matthew Bunn, Senior Research Associate, Project on Managing the Atom
- Hui Zhang, Research Associate, Project on Managing the Atom
- Micah Zenko, Research Associate, Project on Managing the Atom
- Neal Doyle, Program Coordinator, Project on Managing the Atom

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Current research priorities include reducing the threats of nuclear and radiological terrorism; securing, monitoring, and reducing nuclear warhead and fissile material stockpiles; strengthening the global nonproliferation regime; examining the future of nuclear energy, including management of spent nuclear fuel and radioactive wastes, and other means of limiting the proliferation risks of the civilian nuclear fuel cycle; and addressing regional security risks posed by nuclear programs in the Middle East, East Asia, and South Asia.

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