7. Securing Nuclear Stockpiles Worldwide

Matthew Bunn

Key Judgments

- Nuclear terrorism is a real and urgent threat. Both al Qaeda and Aum Shinrikyo (and possibly some Chechen factions) have sought nuclear weapons and the materials to make them. If a sophisticated and well-financed group got separated plutonium or highly enriched uranium (HEU), it is plausible they could make a crude nuclear explosive.
- The most effective tool for reducing this risk is to strengthen security for all nuclear weapons and weapons-usable nuclear materials worldwide. Preventing theft of nuclear weapons and materials would also block a major shortcut for states seeking nuclear weapons. After nuclear material has been stolen, all later lines of defense are variations on looking for needles in haystacks.
- Accurate and transparent accounting of nuclear weapons and materials stockpiles—a key part of a comprehensive nuclear security approach—will also be an essential part of a verifiable path to deep reductions in, or prohibition of, nuclear weapons.
- Although current efforts to improve security for nuclear weapons and materials have made substantial progress, particularly in Russia, unacceptable risks remain. Hundreds of buildings with plutonium or HEU in many countries around the world are de-

monstrably not secured against the kinds of outsider and insider threats that terrorists and criminals have shown they can pose.

- Efforts to improve nuclear security around the world must meet three goals: to improve security *fast enough* so that the security upgrades get there before the thieves do; to improve security to a *high enough level* to protect stockpiles of nuclear weapons and materials against plausible terrorist and criminal threats; and to *sustain* effective security over time. There are inevitable tensions between these three goals, but all must be met to reduce the risk of nuclear terrorism substantially for the long haul.
- The main obstacles to achieving these goals are: (a) complacency about the threat; (b) resistance from nuclear managers and officials who would have to pay the costs and bear the inconveniences of improved security; (c) secrecy; (d) concerns over national sovereignty; (e) bureaucratic inertia; and (f) the sheer difficulty of changing the attitudes and daily behavior (the "security culture") of thousands of people around the world who handle or guard nuclear weapons and materials.

Recommendations

- *Sustained leadership.* The most important ingredient for overcoming the obstacles to securing nuclear stockpiles is sustained leadership from the highest levels of government, in Washington, Moscow, and capitals around the world. The U.S. president should appoint a senior full-time official in the White House to ensure that preventing nuclear terrorism gets the sustained high-level attention it requires, and encourage Russia and other states to do likewise.
- *Explaining the urgency of the threat.* Making the needed action happen will require convincing political leaders and nuclear managers around the world that nuclear terrorism is a real and urgent global threat worthy of their time and resources. A variety of approaches should be pursued to make this case, including joint

briefings on the threat (by U.S. experts and experts from the particular country concerned); nuclear terrorism war games and simulations; fast-paced reviews of whether the nuclear security measures in place are sufficient to defeat specified outsider or insider threats (by experts from each country, or foreign experts if the country so wishes); and realistic tests of the performance of nuclear security systems in defeating plausible outsider and insider threats.

- *A global nuclear security campaign.* The United States and Russia should seek to lead a fast-paced global campaign to achieve effective and sustainable security for all nuclear weapons and weapons-usable nuclear materials worldwide as quickly as practicable, using all policy tools available. The recent Global Initiative to Combat Nuclear Terrorism is one, but only one, of the policy tools that must be brought to bear. This campaign should pursue partnership-based approaches which respect national sovereignty and draw on ideas and resources from all participants—and which can be implemented while protecting nuclear secrets.
- *An expanded and accelerated global cleanout of vulnerable nuclear stockpiles.* A key element of such a campaign must be an expanded and accelerated global effort to remove the weapons-usable nuclear material entirely from vulnerable sites around the world. This must include stronger efforts to convert research reactors from HEU to low-enriched fuels and to shut down unneeded HEU-fueled reactors; expanded efforts to ship the HEU from such sites to secure locations; and targeted incentives to convince states and reactor operators to convert or shut down and give up their HEU.
- *Forging effective global nuclear security standards.* The United States and other leading nuclear weapon and nuclear energy countries should seek to put in place global nuclear security standards that will ensure that all nuclear weapons and every significant cache of plutonium or HEU has adequate protection from theft.

UNSC Resolution 1540 already legally requires all states to provide "appropriate effective" security and accounting for nuclear stockpiles; the United States and its partners should seek a common understanding on the essential elements of such "appropriate effective" systems and seek to help (and pressure) states to put them in place.

- *Building sustainability and security culture.* Another key element of the global campaign will be helping states put in place the resources, organizations, and incentives needed to sustain effective security for the long haul, and strong security cultures. Effective and effectively enforced nuclear security rules are particularly important, as without them, most nuclear managers will not invest in expensive security measures.
- *Beyond nuclear security.* The United States and other leading states should also take new steps to detect and disrupt potential nuclear terrorist groups; interdict nuclear smuggling; deter and prevent nuclear transfers from states to terrorist groups; strengthen the norm against mass slaughter of civilians in the Muslim world and elsewhere; and address the root causes of terrorist violence.

Background

Effectively securing the world's stockpiles of nuclear weapons and the materials needed to make them is the single most effective step that can be taken to reduce the deadly risk of nuclear terrorism—and to block a major potential shortcut for states seeking nuclear weapons as well.[1] Moreover, accurate and transparent accounting of these stocks—an important element of a comprehensive nuclear security

1. This paper addresses only terrorist use of actual nuclear explosives—either stolen nuclear weapons, or crude nuclear explosives terrorists might be able to make from nuclear material they managed to acquire. It does not address more likely but much less catastrophic radiological "dirty bomb" attacks; nor does it address sabotage of major nuclear facilities. It draws heavily on Matthew Bunn, *Securing the Bomb* (Cambridge, Mass.: Project on Managing the Atom, Harvard University and Nuclear Threat Initiative, 2007).

system—is also a key element of a verifiable path to deep reductions in, or prohibition of, nuclear weapons. Unfortunately, the obstacles to rapidly and sustainably achieving stringent standards of security for all nuclear stockpiles worldwide are substantial.

Nuclear terrorism remains a real and urgent danger. The facts that frame the danger are stark.

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.[2] Osama bin Laden has called acquiring nuclear weapons a "religious duty." Despite the post-9/11 disruptions it has faced, the evidence suggests that al Qaeda continues to seek nuclear weapons and the materials and expertise to make them. In his memoir, former Director of Central Intelligence George Tenet provides frightening new information on al Qaeda's nuclear efforts—including a report from a senior al Qaeda operative that the group's nuclear weapons program had advanced to the point of conventional explosive testing. Tenet says that he is "convinced" that Osama bin Laden still "desperately" wants a nuclear bomb.[3] The removal of al Qaeda's sanctuary in Taliban-led Afghanistan and the disruption of al Qaeda's central command reduced the risk, but it appears that al Qaeda is rebuilding in the Pakistan-Afghanistan border areas. U.S. intelligence assesses that the al Qaeda leadership "continues to plan high-impact plots" with "the goal of producing mass casualties," and continues to seek nuclear, chemical, biological, and radiological weapons.[4] Nor is this only an American fear: In late 2005, for example,

2. See discussion in 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 www.nti.org/e_research/cnwm/threat/demand.asp as of January 2, 2007).

3. George Tenet, *At the Center of the Storm: My Years at the CIA* (New York: Harper Collins, 2007), pp. 275, 279.

4. U.S. National Intelligence Council, *National Intelligence Estimate: The Terrorist Threat to the U.S. Homeland* (Washington, D.C.: Office of the Director of

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."[5]

Huge stockpiles of nuclear weapons and potential nuclear bomb material exist worldwide. Today, world stockpiles include some 25,000 nuclear weapons and an estimated 2,300 tons of highly enriched uranium (HEU) or separated plutonium. Nine countries possess nuclear weapons, and U.S. nuclear weapons are physically located in several additional countries. Weapons-usable nuclear materials exist in more than 40 countries, in hundreds of individual buildings. Hundreds of transports of nuclear weapons or potential nuclear bomb material—the part of their life cycles where they are most vulnerable to overt, violent theft—occur every year. Many thousands of people around the world have access to either nuclear weapons or the materials needed to make them.

Some nuclear stockpiles are dangerously insecure. Security at some of these buildings is excellent; at others, it amounts to little more than a night watchman and a chain-link fence.[6] Many sites have security and control measures that are demonstrably insufficient to defeat the kinds of sophisticated insider conspiracies or large-scale outsider attacks that terrorists and criminals have successfully carried out in a variety of countries around the world. No binding global standards currently exist specifying how secure nuclear weapons and the materials needed to make them must be.

Remarkably, it appears that neither the U.S. government nor the

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National Intelligence, 2007; available at www.dni.gov/press_releases/20070717_release.pdf as of August 3, 2007).

5. "Internal Troops to Make Russian State Facilities Less Vulnerable to Terrorists," *RIA-Novosti*, October 5, 2005.

6. For discussion, see, for example, Bunn, *Securing the Bomb*, 2007.

International Atomic Energy Agency (IAEA) yet has a prioritized list assessing which facilities around the world pose the most serious risks of nuclear theft, integrating 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. The most egregious security weaknesses have been fixed, and it is unlikely that one person with no particular plan could steal HEU or plutonium at any nuclear facility in the Russian Federation today, as occurred in several cases in the 1990s. 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. The 2006 firing of Major General Sergey Shlyapuzhnikov, deputy chairman of the section of the Ministry of Interior (MVD) responsible for law and order in the closed territories (including the closed nuclear cities), for helping to organize smuggling in and out of those closed territories, is an indicator of the systemic corruption that creates dangerous possibilities for sophisticated insider conspiracies.[7] 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.

7. "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," *Rossiyskaya Gazeta*, June 2, 2006.

Similarly, in Pakistan, nuclear insiders have met with bin Laden to discuss nuclear weapons, and have marketed sensitive nuclear technologies around the world; the outsider threat includes both a reconstituted al Qaeda and a wide range of other jihadi groups. Serving Pakistani military officers cooperating with al Qaeda operatives have twice come close to assassinating the Pakistani president; who can be confident that officers guarding nuclear weapons will never cooperate with al Qaeda?

HEU-fueled research reactors pose another high-priority theft risk. More than 140 research reactors in dozens of countries 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—again, 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.

Nuclear theft is an ongoing reality. The seizure of stolen 89% enriched HEU in Georgia in early 2006 is a stark reminder that nuclear theft and smuggling is not a hypothetical worry but an ongoing fact of international life. The IAEA has documented some 17 cases of seizure of stolen HEU or separated plutonium confirmed by the states concerned; there are additional cases that certainly occurred (the relevant individuals have confessed and been convicted) but that the relevant states have not yet officially confirmed to the IAEA. U.S. intelligence assesses that additional undetected thefts have occurred.[8]

8. Probably the best available summary of what we know and what we cannot know from the known cases of nuclear and radiological smuggling is "Illicit Trafficking in Radioactive Materials," in *Nuclear Black Markets: Pakistan, A. Q. Khan and the Rise of Proliferation Networks: A Net Assessment* (London: International Institute for Strategic Studies, 2007). There are 18 cases currently on the IAEA's list, but one is a case of discovery of substantial HEU contamination which may not have involved stolen material. For the U.S. intelligence assessment, see U.S. National In-

The critical question which cannot be answered is, How many cases, of what magnitude, have gone undetected?

State transfers to terrorists are a real, but lower, risk. Because of the immense danger of being found out, 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. Such transfers might be more plausible, however, if (a) the state became desperate enough that the money or other items that might be gained in return for nuclear material were seen as critical to the survival of the regime (or of its key leaders), or (b) the regime was convinced that it was about to collapse or be overthrown in any case, and such a transfer was seen as a last act of revenge. In addition, the line between theft-and-transfer and conscious state transfer may not always be a bright one: While the North Korean regime presumably exercises tight control over its small nuclear stockpile, for example (given its importance to the regime), in the pervasive corruption of the North Korean state, one could imagine a scenario in which a leading general (or a small clique of officers) concluded that there was enough plutonium available that a bomb's worth could be sold to terrorists for cash without the rest of the government becoming aware of the transfer. Hence, steps to convince states such as North Korea and Iran to verifiably abandon their nuclear weapons efforts and eliminate any weapons or weapons-usable nuclear material in their possession are clearly also an important part of a nuclear-terrorism-prevention agenda. Efforts to make such transfers more difficult—such as the current program to put radiation detectors at key border cross-

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telligence 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 www.fas.org/irp/nic/russia0406.html as of May 16, 2007).

ings from North Korea into China—should also be pursued, but given the immense difficulties of stopping such transfers, no one should rely on such measures to reduce the risk by more than a few percent.

Nuclear smuggling is extraordinarily hard to stop. Whether terrorists got a nuclear bomb or nuclear material from a state or after 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 or any other large country from nuclear terrorism by detecting and stopping nuclear contraband at the country'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. 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.

The nuclear materials needed to make a nuclear bomb would fit in a suitcase. Moreover, the radioactivity from these materials is weak and difficult to detect from any substantial distance. The radiation detectors now being installed at borders around the world would have little chance of detecting the radiation from a shielded package of HEU. 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.

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 oceangoing yacht, to give just one example.

Despite the difficulties, there is a wide range of steps that can and should be taken to make smuggling more difficult, including measures 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.[9] It is also 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, with global effects. 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 midtown Manhattan on a typical workday, could kill half a million people and cause more than $1 trillion in direct economic damage.[10] 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.[11] Devastating economic aftershocks would reverberate through-

9. See, for example, Rensselaer Lee, "Nuclear Smuggling: Patterns and Responses," *Parameters: U.S. Army War College Quarterly* (Spring 2003; available at carlisle-www.army.mil/usawc/Parameters/03spring/lee.pdf as of July 9, 2007).

10. 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 www.nti.org/e_research/cnwm/cnwm.pdf as of January 2, 2007), pp. 15–19.

11. Ashton B. Carter, Michael M. May, and William J. Perry, *The Day After:*

out the country and the world. America and the world would be transformed forever—and not for the better.

Nor is nuclear terrorism a threat only 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. While 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."[12] In short, insecure weapons-usable nuclear material anywhere is a threat to everyone, everywhere.

Existing programs are making real but insufficient progress in reducing the threat. Since the 1990s, the original seed sown through the vision of Senator Sam Nunn and Senator Richard Lugar in 1991 has grown into a broad suite of programs to reduce nuclear, chemical, and biological threats, sponsored by many countries. Such cooperative 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. As already noted, the progress in the former Soviet Union has been particularly substantial; the most egre-

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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 Stanford, Calif., Harvard and Stanford Universities, Preventive Defense Project, May 2007; available at belfercenter.ksg.harvard.edu/files/dayafterworkshopreport_May2007.pdf).

12. 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 english.safe-democracy.org/keynotes/a-global-strategy-for-fighting-terrorism.html as of July 9, 2007).

gious security weaknesses there (gaping holes in fences, sites with no security camera in the nuclear material area and no detector to set off an alarm if HEU or plutonium is removed) have been fixed. By the end of fiscal year (FY) 2006, more comprehensive U.S.-sponsored security upgrades had been completed for over half of the buildings with weapons-usable nuclear materials and over half of the nuclear warhead sites.[13] The United States and Russia have set a joint goal of completing cooperative upgrades by the end of 2008; while that goal will be very challenging to meet, upgrades at the sites where the two countries have agreed to cooperate are likely to be completed either by the agreed deadline or within a 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).

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? DOE and Rosatom reached an accord in April 2007 on specific steps toward sustainability to take at each Rosatom site, which is a major step forward. 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, many nuclear security improvement efforts are still in their early stages, and significant gaps

13. For a detailed discussion, see Bunn, *Securing the Bomb*, 2007.

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 has been upgraded to levels designed to defeat demonstrated terrorist and criminal threats. U.S. nuclear security cooperation with Pakistan is underway, but what precisely has been accomplished 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. Both sustainability and security culture are likely to be serious issues for nuclear security improvements worldwide (as they are in the United States).

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. Even with its expanded scope, however, the conversion effort will leave roughly 40 percent of the world's currently operating HEU-fueled reactors uncovered. 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 GTRI currently plans to take back less than 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 oth-

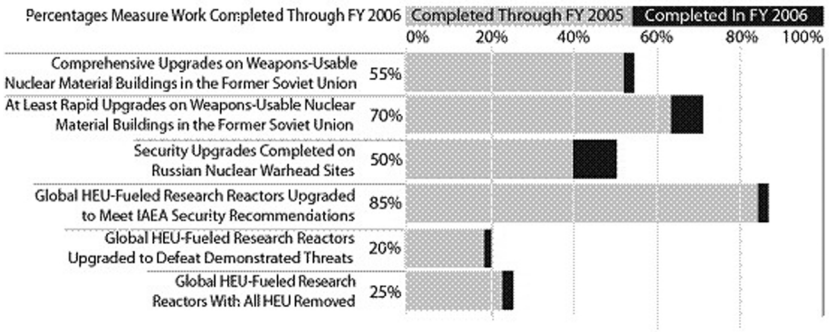

Figure 1. Progress of U.S.-Funded Programs to Secure Nuclear Stockpiles

erwise addressed abroad, and some of it is at sites with highly effective security—but some of it is not. See Figure 1 for a summary of several key measures of the progress of U.S.-funded programs to improve nuclear security.[14] Clearly, while these programs have been excellent investments in U.S. and world security, there is much more yet to be done.

The Global Initiative to Combat Nuclear Terrorism, launched in July 2006, may become 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. Unfortunately, the principles the participants have accepted are extremely general, and there appears to have been little effort to use this format to gain agreement on effective standards for nuclear security that all participants would agree to maintain. As yet, there is little evidence that the initiative has led to any substantial improvements in nuclear security, and the jury is still out on how important it will prove to be.

Issues

Urgent action is needed to prevent a nuclear 9/11. While much has been accomplished—demonstrating the potential for international co-

14. For the data and discussion behind this figure, see Bunn, *Securing the Bomb*, 2007.

operation to reduce the risk—much more remains to be done. Efforts to improve nuclear security around the world must meet three goals: to improve security *fast enough* so that the security upgrades get there before the thieves do; to improve security to a *high enough level* to protect stockpiles of nuclear weapons and materials against plausible terrorist and criminal threats; and to *sustain* effective security over time. There are inevitable tensions between these three goals, as slapped-together systems can be put in place quickly, but may not provide high enough levels of security or be sustainable for the long haul; but all must be met to reduce the risk of nuclear terrorism substantially for the long haul. Success will require addressing several key issues.

How much nuclear security is enough? No nuclear security system can defend against every conceivable threat.[15] Designing nuclear security systems to defend against more capable insider and outsider threats reduces the risk that adversaries might be able to overcome those security systems—but costs more, and creates new inconveniences. Where does the best balance of risk and cost lie?

There is no one clear answer to this question. But given the terrorist threats the world now faces, it seems clear that at a minimum, every nuclear weapon and every significant cache of HEU or separated plutonium worldwide should at least be protected against a modest group of well-trained and well-armed outside attackers (capable of operating in more than one team, and with access to inside information about the security system), one or two well-placed insiders, or both working together. In some countries, where terrorists and thieves are particularly active and capable, it will be necessary to defend against

15. Indeed, while nuclear security improvements can greatly reduce the risk of nuclear terrorism, policymakers should understand that they are not a panacea. If Pakistan becomes a failed state, for example, or a faction allied with the Taliban takes power, better fences and intrusion detectors at its nuclear sites will not solve the problem. Similarly, if a general commanding a nuclear site decides to sell off nuclear material, or 200 well-trained and well-armed attackers assault a facility, most currently contemplated nuclear security measures would be of little help.

even more capable threats to reduce the remaining nuclear terrorism risk to a low level.

How much will it cost, and how long will it take? Here, too, there is no single, well-understood answer. As far as is publicly known, no government or international organization has a listing of all the facilities and transport organizations handling nuclear weapons and weapons-usable materials worldwide and what level of security upgrades they would each require to meet a particular chosen level of security. There is good reason to believe, however, that a further investment in the range of $5 billion would be enough to remove the nuclear stockpiles entirely from the world's most vulnerable sites and provide sufficient security to reduce the risk of nuclear theft at the remaining sites to a low level, and that this could be accomplished within approximately four years. (In current threat-reduction programs, cooperative security upgrades at a site are typically completed within 18 months of the start of work, except at the largest, most complex sites.) There would then be a continuing requirement for hundreds of millions of dollars a year in spending by countries around the world to sustain effective security.

How can we overcome the obstacles that have constrained progress? Rapidly achieving such security standards for all the many caches of nuclear weapons and materials worldwide will not be easy. Key obstacles that will have to be overcome include (a) complacency about the threat; (b) resistance from nuclear managers and officials who would have to pay the costs and bear the inconveniences of improved security; (c) secrecy; (d) concerns over national sovereignty; (e) bureaucratic inertia; and (f) the sheer difficulty of changing the attitudes and daily behavior (the "security culture") of thousands of people around the world who handle or guard nuclear weapons and materials.

Overcoming these obstacles will require a sea-change in the level of sustained leadership from the highest levels of government in Washington, Moscow, and other capitals around the world. Day-in,

day-out engagement will be required, not just occasional encouraging statements. To overcome the current widespread complacency, new steps to convince policymakers and facility managers around the world that nuclear terrorism is a real and urgent threat will be needed; several such steps are recommended below. These steps to increase the sense of urgency should also make policymakers more likely to be willing to override resistance to new nuclear security measures in their nuclear bureaucracies (as occurred in the U.S. Department of Energy (DOE) complex after the 9/11 attacks); bypassing such resistance is also likely to require seeking initial broad commitments at high political levels, where officials are more likely to be able to balance the threat to their nation from the risk of nuclear terrorism against the cost of increased security measures. A range of approaches can make it possible to confirm that a donor state's money is being used appropriately while protecting legitimate nuclear and security secrets—and ongoing cooperation with countries such as Russia and Pakistan makes clear that these approaches can go a long way toward addressing secrecy concerns.

To address concerns over national sovereignty—and to build the kind of "buy in" among the people who will be using and maintaining nuclear security systems—it will be essential to pursue partnership-based approaches to nuclear security cooperation which allow states to choose different approaches to similar nuclear security objectives and which draw on ideas and resources from all participants in ways that serve each of their national interests, not just the donor state's interests.[16] For countries like India and Pakistan, for example, the opportunity to join with the major nuclear states in jointly addressing a

16. For a useful account of what genuinely partnership-based approaches would look like in the U.S.-Russian context, 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 fermat.nap.edu/catalog/11302.html as of July 9, 2007).

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. In the past, concerns over national sovereignty and other obstacles have blocked efforts to negotiate stringent global nuclear security standards in formal treaties, and this is likely to be the case in the near-term future as well; other approaches to forging global standards are recommended below.

Overcoming bureaucratic inertia is likely to require new approaches to institutionalizing high-level attention to the problem in Washington, Moscow, and other leading capitals. Finally, building sustainability and changing security cultures is likely to begin with convincing the staff of nuclear organizations around the world of the reality of the threat; even once that has been accomplished, success is likely to require high-level management commitment and creative approaches.

Recommendations

A Global Campaign to Prevent Nuclear Terrorism

The danger of nuclear theft and terrorism is a global problem, requiring a global response. 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 IAEA may be the forum that other countries most readily accept. 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.

Adapting Nunn-Lugar. The cooperative threat-reduction approaches developed in the former Soviet Union will be a critical tool in achieving the objectives of such a global campaign, which should focus on working with countries around the world to ensure that all stockpiles of nuclear weapons and weapons-usable materials are sustainably secured against the outsider and insider threats terrorists and criminals have shown they can pose. These cooperative approaches will have to be adapted to the circumstances of each country, including its nuclear infrastructure, national culture, secrecy concerns, and more. Pakistan, for example, has now acknowledged that nuclear security cooperation with the United States is taking place, but has made clear that U.S. personnel will not be allowed to visit Pakistani nuclear weapon sites or other sensitive nuclear sites.[17] Tools that have been developed to address such sensitivities in Russia include U.S. provision of equipment that the host state installs at its own expense, without the involvement of U.S. personnel; U.S. reliance on photographs or videotapes to confirm that nuclear security equipment has been installed as agreed, if the United States is paying for the installation; and certification of work done by a "trusted agent," such as an individual with a security clearance from the host country, who is em-

17. Nirupama Subramanian, "Pakistan Accepted U.S. Help on N-Plants," *The Hindu*, 22 June 2006 (available at www.thehindu.com/2006/06/22/stories/2006062205201400.htm as of July 9, 2007).

ployed by a U.S. contractor. Offering reciprocal visits to comparable U.S. sites (such as the Russian visits that have occurred to U.S. nuclear weapon storage sites, nuclear weapons laboratories, and even the U.S. nuclear weapons assembly/disassembly facility) can also be important in addressing such sensitivities, building a sense of partnership, and demonstrating good security practices that might be implemented elsewhere. Similarly, exchanges in key areas such as drafting and enforcing effective nuclear security rules; approaches to assessing vulnerabilities at nuclear sites and designing improvements; methods for testing the real-world performance of nuclear security systems; building strong security cultures; building up appropriate budgetary, training, manufacturing, and maintenance infrastructures for nuclear security; and coping with insider threats can and should be pursued without compromising nuclear secrets, improving countries' ability to ensure effective and sustainable nuclear security on their own through the exchange of best practices and approaches. Similar adaptations of Nunn-Lugar approaches are likely to be necessary in states such as India (where nuclear security cooperation has not yet begun) and China (where such cooperation is in its early stages) as well.

Building the sense of urgency. 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* country's 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:

- *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 and war games.* The United States and other leading countries should organize a series of exercises and war games 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 war game 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 offer lessons for policymakers and facility managers to consider in deciding on nuclear security levels and the steps required in light of those incidents.

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. A plausible standard might be the one described above—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. This would be specific enough to make it possible to hold states accountable for fulfilling their commitment, but general enough to allow each state to take its own approach to nuclear security.

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 comparable 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 such as 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 launched an effort to build such an organization, working with the Institute for Nuclear Materials Management (INMM) and other stakeholders.

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, 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; without that, 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 enough 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. 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 the capacities needed to sustain effective nuclear security, including the necessary procedures, training, and maintenance arrangements.
- 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 an organization focused on nuclear security and accounting, and that these organizations 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 re-

quires—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 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 cultures that build on that experience.

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 im-

mediately 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 re-

search, training, and isotope production out of the smallest number of safe and secure reactors at the lowest cost.

- *An expanded set of reactors.* While the Global Threat Reduction Initiative has expanded it 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), some 40 percent 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, and new steps have been 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). This will require greatly strengthened international police and intelligence cooperation, particularly focused on observable indicators of terrorist nuclear activities, such as attempts to recruit nuclear physicists or metallurgists.
- *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.* The international community must convince North Korea 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).
- *Deter.* The United States should put in place the best practicable means for identifying the source of any nuclear attack and announce 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. A significantly expanded investment in nuclear forensics, and new efforts to convince countries around the world to cooperate in collecting data on the characteristics of nuclear material from different places and processes, should be a key component of this effort. But nuclear forensics must be combined with traditional intelligence approaches, which may often offer more information on where nuclear material may have come from. After all, there were no isotopes to study after the 9/11 attacks, but it did not take long to identify what group, and what individuals, had perpetrated them. Whatever the technical limits of nuclear forensics, the United States and other leading countries should make clear that states that might consider providing nuclear materials to terrorists stand a high risk of being caught and facing overwhelming consequences.

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. A sea-change in the level of sustained leadership

from the highest levels of government in Washington, Moscow, and elsewhere will be essential. The substantial results when top political leaders have taken action—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.

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. At the same time, President Bush should encourage other key national leaders to do the same. In the United States, this 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.

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 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.

Appendix: Nuclear Material Accounting and the Limits of Verification

An accurate and timely nuclear material accounting system is an important part of a comprehensive approach to nuclear security. By confirming whether or not the protected items and materials are still present, a good accounting system can confirm that the other elements of the protection system have worked—or sound the alarm when they have not. Timely and accurate accounting can detect a protracted insider theft while it is still in progress, potentially allowing the theft to be stopped. And a good accounting system can deter potential insider thieves frightened that a theft would be revealed.

On the path to deep reductions and ultimately prohibition of nuclear weapons, it is likely to be increasingly important to monitor not only nuclear weapons stockpiles, but also stockpiles of the plutonium and HEU from which weapons could be made.[18] An accurate and transparent accounting of these stocks will be an important element of a comprehensive verification approach.

Nuclear weapons themselves can simply be counted, and in general states with nuclear weapons are likely to have accurate records concerning their nuclear weapon stockpiles. But when nuclear materials are processed in bulk, inevitable processing losses and measurement uncertainties arise. In a bakery making tons of bread every year, it is impossible to account for every kilogram of flour; much the same is true of a plant processing tons of plutonium every year. Thus, at the end of each year, such a plant will have an "inventory difference," sometimes known as "material unaccounted for"—the difference be-

18. U.S. National Academy of Sciences, Committee on International Security and Arms Control, *Monitoring Nuclear Weapons and Nuclear-Explosive Materials* (Washington, D.C.: National Academy Press, 2005; available at books.nap.edu/catalog/11265.html as of July 9, 2007).

tween what the records say should be on hand and what current measurements say is in fact on hand. No other nation will ever be able to verify a country's nuclear stockpile more accurately than that country can account for it itself, so these uncertainties are important for considering how precise the purely technical results of verification of nuclear material stockpiles can ever be.

Non-nuclear weapon states party to the Nonproliferation Treaty (NPT) are already required to maintain national nuclear material accounting systems that meet acceptable standards of accuracy. Nuclear weapon states and non-parties to the NPT have no such multilateral discipline. During the Cold War, in both the United States and the Soviet Union, the emphasis was on maximizing weapons production, not on accounting for every kilogram. In the 1990s, the United States went through an elaborate process of accounting for its stockpiles, checking its records of production and use of plutonium and HEU against the stockpiles that still existed. These reports indicated that 2.8 tons of plutonium and some 3.2 tons of HEU is officially "inventory differences," with another 3.4 tons of plutonium and 4.9 tons of HEU considered to have been lost to waste—enough material in total for many hundreds of nuclear weapons. It will never be possible to verify that these amounts are precisely correct.

Russia has not yet undertaken a similar exercise of matching production and usage records to current stocks (though for a period the United States and Russia discussed cooperating on such an effort). But it seems clear that its Cold War accounting was less accurate than the U.S. system; its accounting systems were designed to ensure that sites met production quotas, not to detect theft, and at many sites the difference between output and input was simply *defined* as losses to waste, defining away the very possibility that material had been stolen. While improved material accounting equipment has been put in place at many sites, most sites with large inventories of material built up over decades have still not performed an actual measured physical inventory to confirm whether all their hundreds or thousands of can-

isters of nuclear material still contain the material the paper records say they do. China, France, Britain, India, and Pakistan, with their much smaller military nuclear programs, will presumably have smaller uncertainties in their accounting—but it seems likely that in all these cases the irreducible uncertainties will amount to several bombs' worth of nuclear material.

The United States found, in preparing its inventory analyses, that the original production records and the knowledge of the people who produced them were crucial to an accurate understanding of what happened. Around the world, records from decades ago are being thrown out, and the people involved are retiring or dying. Similarly, if "nuclear archaeology" techniques are going to be used to help confirm that levels of production that might be declared in an arms reduction agreement are consistent with the physical condition of the production facilities, it will be crucial to get that work done before these facilities are decommissioned and destroyed.[19]

In short, it would be highly desirable to undertake cooperative efforts to improve nuclear material accounting worldwide, to contribute both to nonproliferation and arms reduction—and there is some urgency in doing so, driven not only by the need to strengthen security against nuclear theft but also by the ongoing and impending loss of crucial information to improve the accuracy of the accounting.[20] Given the sensitivities that still exist, it may be important to begin with helping countries improve their own accounting, rather than insisting

19. Steve Fetter, "Nuclear Archaeology: Verifying Declarations of Fissile Material Production," *Science & Global Security* 3 (1993; available at www.princeton.edu/~globsec/publications/pdf/3_3-4Fetter.pdf as of August 7, 2007).

20. Thomas B. Cochran and Christopher Paine of the Natural Resources Defense Council were early advocates of rapid U.S.-Russian, and ultimately global, cooperative efforts to measure, tag, and seal nuclear materials, as an approach that would contribute to both nonproliferation and disarmament. See, for example, Thomas B. Cochran and Christopher Paine, "Nuclear Warhead Destruction" (Washington, D.C.: Natural Resources Defense Council, 1993; available at docs.nrdc.org/nuclear/nuc_11169301a_118.pdf as of August 7, 2007).

that they provide detailed information on their stockpiles to others. In particular, the United States should work to convince and assist Russia in preparing a detailed accounting of Russia's stockpiles as they compare to what was originally produced (and to preserve production records and knowledge to the extent possible)—without insisting, for the present, that Russia provide the resulting data to the United States.