Securing the Bomb 2008

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EXECUTIVE SUMMARY

The U.S. president who takes office in January 2009 will face a world in which the danger that terrorists could get and use a nuclear bomb remains very real. The purpose of this report is to outline the danger of nuclear terrorism, assess what has and has not been done to reduce it, and suggest an agenda of actions that could reduce the risk dramatically. 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.

Terrorists are still seeking nuclear weapons—and al-Qaeda is reconstituting its ability to plan and conduct complex operations in the mountains of Pakistan. If a technically sophisticated terrorist group could get the needed nuclear materials, it might well be able to make at least a crude nuclear bomb—capable of turning the heart of a modern city into smoldering ruins. The horror of a terrorist nuclear attack, should it ever occur, would transform America and the world—and not for the better.

But despite substantial progress in improving nuclear security, some stockpiles of potential bomb material remain dangerously insecure. In Russia, there have been major improvements in nuclear security—the difference between the security in place at many nuclear sites today and the security in place in 1994 is like night and day. But Russia has the world's largest stockpiles of nuclear weapons and materials, located in the world's largest number of buildings and bunkers; some serious security weaknesses still remain, ranging from poorly trained, sometimes suicidal guards to serious under-funding of nuclear security; and the upgraded security systems must face huge threats, from insider theft conspiracies to terrorist groups who have shown an ability to strike in force, without warning or mercy. In Pakistan, a relatively small nuclear stockpile, believed to be heavily guarded, faces even more severe threats, both from nuclear insiders with violent Islamic extremist sympathies and from outsider attack, potentially by scores or hundreds of al-Qaeda fighters. Some 130 nuclear research reactors around the world still use highly enriched uranium (HEU) as their fuel, and many of these have only the most modest security measures in place—in some cases, no more than a night watchman and a chain-link fence.

The break-in by armed attackers at the Pelindaba site in South Africa in November 2007—a site with hundreds of kilograms of weapon-grade uranium—is a reminder that nuclear security is a global problem, not just a problem in the former Soviet Union. And incidents such as the inadvertent flight of six nuclear warheads to Barksdale Air Force Base make it clear that nuclear security requires constant vigilance, and that every country where these stockpiles exist, including the United States, has more to do to ensure that they are effectively secured.

Programs sponsored by the United States and other countries are making major progress in addressing these dangers, representing an excellent investment in U.S. and world security. There is no doubt that the risk of nuclear terrorism today is substantially less than it would have been had these programs never existed. But much more must be done to reduce the risk.

Tables ES-1, ES-2, ES-3, and ES-4 summarize the current state of progress and the work remaining to be done on improving security for nuclear warheads and materials; consolidating those stockpiles into fewer locations and removing them from vulnerable, difficult-to-defend sites; and putting in place the international and domestic policy frameworks needed to achieve effective and lasting nuclear security worldwide.

Table ES-1: Strengthening Nuclear Security: Progress by Category of Country

Category	Assessment
Russia	Dramatic progress, though major issues remain. Planned U.S.-sponsored security upgrades for both warhead sites and nuclear material buildings almost complete, though some warhead sites and material buildings not covered. Inadequate Russian investment to ensure sustainability, though signs of improvement. Questions on security culture. Poorly paid and trained conscript guards for nuclear material. Substantial threats from widespread insider corruption and theft. Substantial outsider threats as well, though suppressed by counterinsurgency in Chechnya.
Developing states with nuclear weapons (Pakistan, India, China, North Korea)	Progress in some areas, not in others. Significant cooperation with Pakistan, but specifics classified. Severe threats in Pakistan from nuclear insiders with jihadist sympathies, al Qaeda or Taliban outsider attacks, and a weak state. India has so far rejected nuclear security cooperation. Broad dialogue with China, but little evidence yet that this has led to substantial improvements on the ground. No effort yet to engage with North Korea on nuclear security cooperation, but very small stock and garrison state probably limit risks of nuclear theft.
Developing and transition non-nuclear-weapon states	Some progress. Upgrades completed at nearly all facilities with weapons-usable material in the Eurasian states outside of Russia, and in Eastern Europe. Belarus, Ukraine, and South Africa have particularly dangerous nuclear material: upgrades completed in Ukraine (though sustainability is an issue); upgrades nearing completion after a several-year delay in Belarus; South Africa hosted an IAEA security review team after the Pelindaba break-in, but has declined nuclear security cooperation with the United States. Upgrades completed for nearly all HEU-fueled research reactors that previously did not meet IAEA recommendations, but most upgrades would not be enough to defend against demonstrated terrorist and criminal capabilities.
Developed Countries	Some progress. Several countries have strengthened nuclear security rules since 9/11. The United States has ongoing dialogues with key countries on nuclear security, but does not sponsor security upgrades in wealthy countries. Nuclear security requirements in some countries remain insufficient to protect against demonstrated terrorist or criminal threats. The Global Initiative to Combat Nuclear Terrorism and the newly established World Institute for Nuclear Security (WINS) may provide fora for discussing nuclear security improvements in developed countries.
United States	Substantial progress, though issues remain. DOE has drastically strengthened its requirements for protecting both nuclear weapons and materials (especially from outsider attack) since 9/11. NRC has also increased its security requirements, though requirements for NRC-regulated facilities with large quantities of HEU are far below those at DOE. NRC-regulated research reactors fueled with HEU remain exempted from most NRC security requirements.

Source: Author's estimates.

Table ES-2: Consolidating Nuclear Stockpiles: Progress by Category of Country

Category	Assessment
Russia	Limited progress, major obstacles. Nuclear weapon sites reduced during 1980s-1990s pullbacks – but nuclear weapons continue to be stored at dozens of separate sites, with no apparent movement toward further consolidation. Russia has the world's largest number of HEU-fueled research reactors, and has largely refused to engage on converting them to Low Enriched Uranium or shutting them down. The Russian Navy has greatly reduced its sites with HEU, and at least one facility has given up all its HEU as part of the Materials Consolidation and Conversion program. Russia has closed down nuclear weapons work at several sites, and some of the remaining sites have moved nuclear material into a smaller number of buildings. But potential bomb material still exists in over 200 buildings, and the Russian government appears unwilling to pursue large-scale consolidation.
Developing states with nuclear weapons (Pakistan, India, China, North Korea)	Limited progress – but these countries have small nuclear stockpiles at small numbers of sites, so less consolidation is needed. China has joined the reactor conversion effort and has converted three research reactors and shut down one more. India is planning to convert one HEU-fueled research reactor to LEU without U.S. help. Growing nuclear arsenals may be stored at larger number of sites in the future. China and India are both pursuing civilian plutonium programs that may eventually lead to widespread use of plutonium fuels.
Developing and transition non-nuclear-weapon states	Substantial progress, but a great deal more to be done. Global Threat Reduction Initiative has accelerated the pace of converting HEU-fueled research reactors to LEU and of shipping Soviet-supplied HEU back to secure sites in Russia; the pace of returning U.S.-supplied HEU has not increased, however. Twelve U.S.-supplied countries and four Soviet-supplied countries (Latvia, Georgia, Iraq, and Bulgaria) have had all their HEU removed. Ukraine has a particularly dangerous stockpile of HEU, which it has agreed in principle to downblend. Belarus and South Africa, which also have particularly dangerous HEU stockpiles, have not yet agreed to eliminate those stocks. Reactors in Ukraine and South Africa have been converted to LEU fuel.
Developed Countries	Some progress, but a great deal more to be done. GTRI has accelerated the pace of converting HEU-fueled research reactors to LEU, and GTRI's "gap materials" effort has brought tens of kilograms of fresh HEU back to the United States from countries such as Canada, Belgium, and the Netherlands. Only a small portion of HEU in these countries is currently targeted for removal, however, and many facilities have little interest in giving up the use of HEU. No programs are in place to minimize the locations where plutonium fuels are used, and the current approach to the Global Nuclear Energy Partnership (GNEP) may have the opposite effect.
United States	Substantial progress, though issues remain. U.S. nuclear weapons are now stored at a small number of sites, though tactical bombs remain at several sites in Europe. NNSA is funding the conversion to LEU of several U.S. HEU-fueled reactors per year. DOE is substantially consolidating its sites and buildings with potential bomb material, though not as quickly or comprehensively as some experts have recommended. The planned MOX program for plutonium disposition would add a small number of reactors to sites with material of concern, and the current approach to GNEP, if funded, could lead to expansion of such sites.

Source: Author's estimates.

Table ES-3: Building International Policy Frameworks: Progress by Category of Effort

Category	Assessment
Building the sense of urgency and commitment worldwide	Some progress, but major obstacles still to overcome. Global Initiative to Combat Nuclear Terrorism and expanded dialogues with foreign intelligence agencies have helped heighten international awareness of the threat. Many nuclear officials and policymakers in key countries, however, continue to believe that it would be almost impossible for terrorists to get the material for a nuclear bomb or to make a bomb from it if they did get hold of it.
Creating a fast-paced global nuclear security campaign	Some progress, but important gaps remaining. The Global Initiative to Combat Nuclear Terrorism has highlighted the threat with many countries, but has focused more on issues such as law enforcement, radiation detection, and emergency response. The Global Partnership Against the Spread of Weapons and Materials of Mass Destruction has moved slowly and spent very little on upgrading security for nuclear stockpiles. Most countries with nuclear stockpiles not yet focused on rapidly improving the security for these stocks and helping other countries to do the same. WINS will help exchange nuclear security best practices, and may help focus attention on the threat.
Forging effective global nuclear security standards	Limited progress. Neither the amended physical protection convention nor the nuclear terrorism convention set standards for how secure nuclear stockpiles should be. UN Security Council Resolution 1540 legally obligates all states to provide "appropriate effective" security and accounting for nuclear stockpiles, but there is no agreed definition of what essential elements are needed to meet this requirement. Discussions of a revision to IAEA physical protection recommendations that might provide more specific standards are under way.
Building strong nuclear security partnerships	Some progress, more to be done. The Global Initiative to Combat Nuclear Terrorism, co-chaired by the United States and Russia, has put Russia in the role of joint leader of a global effort, rather than only recipient of assistance. Since the Bratislava summit, U.S.-Russian discussions have included more genuine exchanges of approaches and best practices. But souring U.S.-Russian relations in the aftermath of the conflict in Georgia may make new cooperative agreements and real partnership more difficult to achieve – though existing nuclear security cooperation has not been cut back. Russia is still under-investing in nuclear security at home (relying heavily on U.S. funding at many Russian sites), and refusing to invest in upgrading security or consolidating stockpiles elsewhere. U.S. decisions on issues such as Georgia, missile defenses in Europe, NATO expansion, and Kosovo are being taken with limited consideration of the potential impact on nuclear security cooperation. Efforts to begin building nuclear security partnerships with other countries are just beginning.
Achieving Sustainability	Significant progress in Russia, limited progress elsewhere. U.S. and Russian governments have reached accord on sustainability principles, are working to lay out sustainability plans for each site – but Russia still investing less than is likely to be needed. In other countries, there have been less extensive upgrades and less focus on putting in place the resources, organizations, and incentives needed to ensure that high levels of nuclear security are sustained.
Strengthening security culture	Some progress in Russia, limited progress elsewhere. U.S. and Russian governments have established a security culture pilot program at 10 facilities in Russia, and developed a joint methodology for security culture assessment, but much more remains to be done. The IAEA's first document providing guidance on assessing and strengthening security culture has just been issued, after years of delay. Many nuclear managers and staff remain convinced that security threats are minimal and further measures are not required. WINS should provide a forum for exchanging best practices in strengthening security culture.

Source: Author's estimates.

Table ES-4: Building Domestic Policy Frameworks: Progress by Category of Effort

Category	Assessment
Putting someone in charge	Little progress. Congress passed, and President Bush signed into law, legislation requiring the appointment of a full-time White House official to lead efforts to prevent nuclear, chemical, and biological proliferation and terrorism, but no such official has been appointed.
Developing and implementing a comprehensive, prioritized plan	Little progress. Congress passed, and President Bush signed into law, legislation requiring the development of a comprehensive plan to ensure that all nuclear weapons and all stocks of plutonium and HEU worldwide were sustainably secured against demonstrated terrorist and criminal capabilities by 2012. To date, however, there is no public indication that the administration will do more than stapling together the pre-existing plans of various programs focused on nuclear security, which, even in combination and even if wholly successful, would not cover all stocks of plutonium and HEU worldwide. The Nuclear Materials Information Program is working to collect and analyze the data on nuclear materials and their security worldwide that would provide the basis for such a plan.
Providing sufficient resources, matched to priorities	Significant progress, but more to be done. Spending on programs to reduce the risk of nuclear terrorism has increased substantially, and money is now a less important constraint than cooperation for most programs. No consistent process in place, however, to assign funds to the highest-priority efforts or to reassign funds as new opportunities arise. Some programs could accelerate progress now if provided additional funds. If other policies could break through the political and bureaucratic obstacles to cooperation, more money would be needed to implement an accelerated program.
Overcoming bureaucratic impediments	Significant progress, but more to be done. Congress has removed the threat-reduction certification requirements that slowed progress, and has consolidated some reporting requirements. Cumbersome contracting procedures, difficulties between NNSA and DOD and their labs and contractors, and other issues continue to impede progress.
Building a sustainable coalition of support	Significant progress, but more to be done. Broad support for most nuclear security programs on Capitol Hill and from both presidential candidates. But in many cases, pro-active initiatives still depend on a tiny handful of members of Congress. Little active support from private industry, as there are no large firms that get more than a few percent of their revenue from these programs. Broad public support is unfocused and results in little active pressure for expanded and accelerated efforts.

Source: Author's estimates.

This report focuses primarily on efforts to secure and remove nuclear weapons and the materials needed to make them, in order to keep them from being stolen, for these steps offer the most effective means to reduce 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.

Nevertheless, a comprehensive approach to reducing the risk of nuclear terrorism would also include efforts to block other steps on the terrorist pathway to the bomb, including new efforts to disrupt terrorist nuclear plots and their financing and recruitment; to interdict nuclear smuggling; to prevent and deter conscious state decisions to transfer nuclear weapons or materials to terrorists; to impede terrorist recruitment of nuclear experts; to reduce global stockpiles of nuclear weapons and fissile materials, and to end new production; and to place these stockpiles under international monitoring.

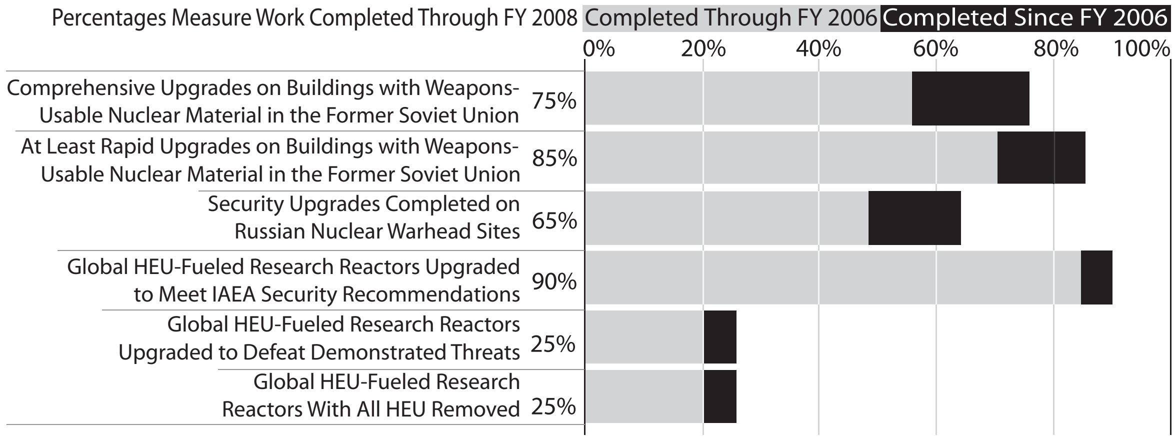
Quantitative indicators of progress in securing nuclear stockpiles can never be more than rough suggestions of the state of a more complex picture, as difficult-to-measure questions can also be central to effective nuclear security, from how effective the guard force is to the degree to which the staff at a site cuts corners on nuclear security rules. Nevertheless, these indicators make clear that while a great deal has been accomplished to secure nuclear material around the world, a great deal more remains to be done. As of the end of fiscal year (FY) 2008, comprehensive security upgrades had been completed for roughly 75 percent of the buildings in the former Soviet Union that contain weapons-usable nuclear material, and U.S. and Russian experts were rushing to complete agreed upgrades by the end of 2008. At the same time, however, while the Department of Energy's (DOE) Global Threat Reduction Initiative (GTRI) has greatly accelerated security upgrades, conversion to low-enriched uranium, and HEU removals at HEU-fueled research reactors, some three-quarters of these facilities have not yet had their HEU removed or had their security upgraded to a level that would provide effective protection against demonstrated terrorist and criminal threats. Figure ES-1 provides a summary of these quantitative indicators.

Most programs intended to reduce the risk of nuclear terrorism are constrained more by limited cooperation (resulting from secrecy, complacency about the threat, concerns over national sovereignty, and bureaucratic impediments) than they are by limited budgets. Nevertheless, the fact that the entire budget for all programs to prevent nuclear terrorism comes to less than one-quarter of one percent of the defense budget makes a clear statement about whether this effort is really a top priority of the U.S. government—and makes clear that the U.S. government could easily afford to do more, if more effort is needed. For FY 2009, the Bush administration requested $1.083 billion for all programs to improve controls over nuclear weapons, materials, and expertise overseas, an 18 percent reduction from the FY 2008 appropriation. Several programs, particularly GTRI, have opportunities to make more rapid progress if they had additional funds: GTRI in particular would require an increase of $200 million or more to seize all the opportunities to reduce nuclear terrorism risks it now has available—though managing such a rapid expansion in the program's efforts would be a significant challenge.

Preventing Nuclear Terrorism: An Agenda for the Next President

Preventing a terrorist nuclear attack must be a top international security priority—for the next U.S. president, and for leaders around the world. While the obstacles to accelerated and expanded progress are real and difficult, with sustained high-level leadership, a sensible strategy, and

Figure ES-5: Progress of U.S.-Funded Programs to Secure Nuclear Stockpiles



Source: Author's estimates. (See Chapter 3 for details).

adequate resources, they can be overcome. The next U.S. president has an historic opportunity—an opportunity to reduce the danger of nuclear terrorism to a fraction of its current level during his first term in office.

Achieve effective and lasting nuclear security

Launch a fast-paced global nuclear security campaign. The next U.S. president, working with other world leaders, should forge a global campaign to lock down every nuclear weapon and every significant stock 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. The Global Initiative to Combat Nuclear Terrorism is a first step, which has been valuable in focusing countries' attention on the issue of nuclear terrorism and building legal infrastructure, capacity for emergency response, law enforcement capabilities, and more—but it has not focused on rapid and substantial security upgrades for nuclear stockpiles, and demands little of countries to count as partners. A modified approach—focused on locking down all stocks of nuclear weapons, plutonium, and HEU to high standards—is likely to be necessary to create the kind of fast-paced nuclear security campaign that is needed. To succeed, such an effort must 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, it is politically untenable to accept U.S. assistance that is portrayed as necessary because they are unable to adequately control their nuclear stockpiles on their own. But joining with the major nuclear states in jointly addressing a global problem may be politically appealing. U.S.-Russian relations have gone into a tailspin since the conflict in Georgia, making a real nuclear security partnership with Russia far more difficult to achieve, but no less essential; shared U.S.-Russian interests in keeping nuclear material out of terrorist hands remain. Such partnerships will have to be based on creative 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.

Seek to ensure that *all* nuclear weapons, plutonium, and highly enriched uranium are secure. Terrorists will get the material to make a nuclear bomb wherever it is easiest to steal. The world cannot afford to let stovepipes between different programs leave some vulnerable stocks without security upgrades—the goal must be to ensure effective security for *all* stocks worldwide. Today, security upgrades in Russia are nearing completion, and there is significant progress in Pakistan, but the promising nuclear security dialogue with China does not yet appear to have led to major improvements in nuclear security there, and India has so far rejected offers of nuclear security cooperation. Upgrades in Belarus were delayed for years by poor political relations (though they are now nearly completed), and South Africa has not yet accepted nuclear security cooperation, despite the break-in at Pelindaba (although it did host an IAEA-led nuclear security review team after that incident). Except for occasional bilateral dialogues, U.S. programs largely ignore stocks in wealthy developed countries, though some of these, too, are dangerously insecure. Sustained high-level leadership is needed to close these gaps. While specific tactics are likely to differ—achieving security upgrades in wealthy countries may be more about convincing them that action is needed than it is about paying for it ourselves—it is urgent to get past the assumption that everything in wealthy countries is adequately secured.

Expand and accelerate efforts to consolidate nuclear stockpiles. The next U.S. president should place higher priority on working with countries to reduce drastically the number of sites where nuclear weapons and the materials to make them exist, achieving higher security at lower cost. The goal should be to remove all nuclear material from the world's most vulnerable sites and ensure effective security wherever material must remain within four years or less—and to eliminate HEU from all civilian sites worldwide within roughly a decade. The GTRI has greatly accelerated the pace at which research reactors are being converted from HEU to low-enriched uranium (LEU) that cannot be used in a nuclear bomb, and the pace of removing HEU from these sites to secure locations. But here, too, there are gaps that should be closed. New incentives should be offered so that much of the more than 13 tons of U.S.-origin HEU not covered in current GTRI removal plans will be sent back or otherwise eliminated. A new program should be established to give unneeded reactors incentives to shut down (an approach which may be cheaper and quicker than conversion, especially for difficult-to-convert reactors). Over time, the United States should seek an end to all civil use of HEU. New efforts should be undertaken to limit the production, use, and stockpiling of weapons-usable separated civilian plutonium—including renewing the nearly-completed late-1990s effort to negotiate a 20-year U.S.-Russian moratorium on plutonium separation. And as nuclear energy expands and spreads, the United States should not encourage that spread to be based on approaches that involve reprocessing and recycling of plutonium, as some of the approaches envisioned in the Global Nuclear Energy Partnership (GNEP) would do; even the proposed GNEP processes that do not separate "pure plutonium" would tend to increase, rather than decrease, the risk of nuclear theft and proliferation compared to not reprocessing this fuel.

Gain agreement on effective global nuclear security standards. As nuclear security is only as strong as its weakest link, the world urgently needs effective global nuclear security standards that will ensure that all nuclear weapons and weapons-usable materials are protected against the kinds of threats terrorists and criminals have shown they can pose—at a bare minimum, against two small teams of well-trained, well-armed attackers, possibly with inside help, as occurred at Pelindaba. (In some countries, protection against even more capable threats is needed.) UN Security Council Resolution 1540 legally requires all countries to provide "appropriate effective" security and accounting for all their nuclear stockpiles. The time has come to build on that requirement by reaching a political-level agreement with other leading states on what the essential elements of appropriate effective security and accounting systems are, and then working to ensure that all states put those essential elements in place. Ultimately, effective security and accounting for weapons-usable nuclear material should become part of the "price of admission" for doing business in the international nuclear market.

Build sustainability and security culture. If the upgraded security equipment the United States is helping countries put in place is all broken and unused in five years, U.S. security objectives will not be accomplished. The next U.S. president should step up efforts to gain top-level commitments from Russia and other countries to sustain effective nuclear security for the long haul with their own resources. He should also intensify programs to work with countries around the world to build strong security cultures, putting an end to staff propping open security doors for convenience or guards patrolling with no ammunition in their guns. Building strong security cultures is a difficult policy challenge; the most important single element is convincing nuclear managers and all their security-relevant staff of the urgency of the threat (see "Leadership and Commitment," below). As most nuclear managers only invest in expensive security measures when the government tells them they have to, effective regulation is essential to effective and lasting security; the next U.S. president should greatly increase the focus on ensuring that countries around the world put in place and enforce effective nuclear security and accounting regulations.

Beyond nuclear security

Beefing up nuclear security, so that nuclear material cannot be stolen and fall into terrorist hands, is the single step that can most reduce the risk of nuclear terrorism—the critical chokepoint on the terrorist pathway to the bomb. Once potential bomb material is outside the gate of the facility where it is supposed to be, it could be anywhere, and the difficulty of stopping a terrorist nuclear plot increases dramatically. Nevertheless, theft-prevention efforts cannot be expected to be perfect; an integrated system of approaches to stopping terrorist nuclear plots is needed.

Disrupt: counter-terrorism efforts focused on nuclear risks. The next U.S. president should work with other countries to build an intense international focus on stopping the other elements of a nuclear plot—the recruiting, fundraising, equipment purchases, and more that would inevitably be required. Because of the complexity of a nuclear effort, these would offer a bigger and more detectable profile than many other terrorist conspiracies—although, as U.S. intelligence officials have pointed out, the observable "footprint" of a nuclear plot might be no bigger than that of the 9/11 plot. The best chances to stop such a plot lie not in exotic new detection technologies but in a broad counter-terrorist effort, ranging from intelligence and other operations to target high-capability terrorist groups to addressing the anti-American hatred that makes recruiting and fund-raising easier, and makes it more difficult for other governments to cooperate with the United States. In particular, the United States should work with governments and non-government institutions in the Islamic world to build a consensus that slaughter on a nuclear scale is profoundly wrong under Islamic laws and traditions (and those of other faiths)—potentially making it more difficult for those terrorists wanting to pursue nuclear violence to convince the people they need to join their cause.

Interdict: countering the nuclear black market. Most of the past successes in seizing stolen nuclear material have come from conspirators informing on each other and from good police and intelligence work, not from radiation detectors. The next U.S. president should work with other countries around the world to intensify police and intelligence cooperation focused on stopping nuclear smuggling, including additional sting operations and well-publicized incentives for informers to report on such plots, to make it even more difficult for potential nuclear thieves and buyers to connect. The United States should also work with states around the world to ensure that they have (a) units of their national police forces trained and equipped to deal with cases of smuggling of nuclear materials and weapons-related equipment, and other law enforcement personnel trained to call in those units as needed; (b) effectively enforced laws on the books and making any participation in real or attempted theft or smuggling of nuclear weapons or weapons-usable materials, or nuclear terrorism, crimes with penalties comparable to those for murder or treason; (c) a commitment to catching and prosecuting those involved in such transfers; and (d) standard operating procedures, routinely exercised, to deal with materials that may be detected or intercepted. The next U.S. president should develop an approach that offers a greater chance of stopping nuclear smugglers at lower cost than the current mandate for 100 percent scanning of all cargo containers, focusing on an integrated system that places as many barriers in the path of intelligent adversaries attempting to get nuclear material into the United States by *any* pathway as can be accomplished at reasonable cost, and work with Congress to get the modified approach approved. (In particular, it is important to understand that neither the detectors now being deployed nor the Advanced Spectroscopic Portals will have any substantial chance of detecting HEU metal with even modest shielding.)

Prevent and deter: reducing the risk of nuclear transfers to terrorists by states. Conscious state decisions to transfer nuclear weapons or materials to terrorists are a small part of the overall risk of nuclear terrorism; hostile dictators focused on preserving their regimes are highly unlikely to hand over the greatest power they have ever acquired to groups they cannot control, in ways that might provoke retaliation that would destroy their regimes forever. Nevertheless, this risk is not zero, and steps should be taken to reduce it further. 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 strengthened significantly, reducing the chances that other states might someday gain nuclear weapons that might fall into terrorist hands. 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 and law enforcement 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. This should include both increased funding for R&D and expanded efforts to put together an international database of material characteristics. Policymakers should understand, however, that nuclear material has no DNA that can provide an absolute match: nuclear forensics will complement other sources of information, but will rarely make clear where material came from by itself.

Respond: global nuclear emergency response. The next U.S. president 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 nuclear emergency search teams (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.

Impede: impeding terrorist recruitment of nuclear personnel. The next U.S. president should maintain existing scientist-redirection programs, but should reform them to use a broader array of tools and to focus on a broader array of threats, including not only top weapons scientists but workers with access to nuclear material, guards who could help steal nuclear material, and people who have retired from nuclear facilities but still have critical knowledge. The United States is not likely to have either the access or the resources to carry out this broader mission by itself, but must work closely with partner countries to convince them to take most of the needed actions themselves. The next U.S. president should also work with key countries such as Russia and Pakistan to strengthen control of classified nuclear information and ensure that they monitor contacts and behavior of all individuals with key nuclear secrets—and should work with a broader set of countries to monitor and stop recruitment attempts at key sites, such as physics and nuclear engineering departments in countries with substantial Islamic extremist communities.

Reduce: reducing stockpiles and ending production. The United States, Russia, and other nuclear weapon states should join in an effort to radically reduce the size, roles, and readiness of their nuclear weapon stockpiles, verifiably dismantling many thousands of nuclear weapons and placing the fissile material they contain in secure, monitored storage until it can be safely and securely destroyed. Very deep reductions in nuclear stockpiles, if properly managed, would reduce the risks of nuclear theft—and could greatly improve the chances of gaining international support for other nonproliferation steps that could also reduce the long-term dangers of nuclear theft. As a first step, the next U.S. president should launch a joint program with Russia to reduce total U.S. and Russian stockpiles of nuclear weapons to something in the range of 1,000 weapons, and to place all plutonium and HEU beyond the stocks needed to support these low, agreed warhead stockpiles (and modest stocks for other military missions, such as naval fuel) in secure, monitored storage pending disposition. In particular, the United States and Russia should launch another round of reciprocal initiatives, comparable to the Presidential Nuclear Initiatives of 1991-1992, in which they would each agree to: (a) take several thousand warheads—including, but not limited to, all tactical warheads not equipped with modern, difficult-to-bypass electronic locks—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. The next U.S. president should also reverse the Bush administration's misguided opposition to a verified fissile material cutoff treaty, and lead work with other governments to overcome the obstacles to negotiating such a treaty—while also seeking to end all production of HEU for any purpose, and to phase out civilian separation of weapons-usable plutonium.

Monitor: monitoring nuclear stockpiles and reductions. The next U.S. president should work with Russia to revive efforts to put in place a system of data exchanges, reciprocal visits, and monitoring that would build confidence in the size and security of each side's nuclear stockpile, lay the groundwork for deep reductions in nuclear arms, and confirm agreed reductions in nuclear warhead and fissile material stockpiles. Such a system should ultimately be expanded to cover other nuclear weapon states as well. In particular, the next U.S. president should seek Russian agreement, before the 2010 Nonproliferation Treaty (NPT) review, that each country will place large quantities of excess fissile material under IAEA monitoring.

Leadership and commitment

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 and creative leadership at many levels—at the highest levels of key governments around the world; in nuclear ministries and regulatory agencies; among intelligence, police, customs, and border control agencies; and at every nuclear facility or transport organization that handles nuclear weapons, plutonium, or HEU. Leadership from the next U.S. president will be particularly critical, for the United States is the single country most focused on reducing the threat of nuclear terrorism. Several steps will be critical to overcoming the obstacles to expanded and accelerated progress in reducing the risk.

Building the sense of urgency and commitment worldwide. The fundamental key to success is 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 money—something many of them do not believe today. If these programs succeed in building that sense of urgency, these officials and managers will take the needed actions to prevent nuclear terrorism; without that sense of urgency, they will not. Some of this case is already being made, especially in the context of the Global Initiative to Combat Nuclear Terrorism and in discussions between key U.S. intelligence officials and their foreign counterparts, but much more needs to be done. The United States and other countries should take several steps to build the needed sense of urgency and commitment, including: (a) *joint threat briefings* at upcoming summits and high-level meetings with key countries, where experts from both the United States and the country concerned would outline the very real possibility that terrorists could get nuclear material and make a nuclear bomb; (b) *nuclear terrorism exercises* with policymakers from key states, which can sometimes reach officials emotionally in a way that briefings and policy memos cannot; (c) *fast-paced nuclear security reviews,* in which leaders of key states would pick teams of security experts they trust to conduct fast-paced reviews of nuclear security in their countries (with U.S. advice and technical assistance if desired), assessing whether facilities are adequately protected against a set of clearly-defined threats (as the United States did after 9/11, revealing a wide range of vulnerabilities); (d) *realistic testing of nuclear security performance,* in which the United States could help countries conduct realistic tests of their nuclear security systems' ability to defeat realistic insider or outsider threats; and (e) *shared databases of threats and incidents,* including 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 particular threats to defend against.

Putting someone in charge. The steps needed to prevent nuclear terrorism cut across multiple cabinet departments, and require cooperation in highly sensitive areas with countries across the globe. They will require sustained effort, day-in and day-out, from the highest levels of the U.S. government—and other governments. Yet today, there is no one in the U.S. government with full-time responsibility for all of the disparate efforts to prevent nuclear terrorism. The president who takes office in January 2009 should appoint a senior White House official who has the president's ear—probably a Deputy National Security Advisor, though the specific title would depend on the person and the structure of the NSC—whose sole responsibility will be to wake up every morning thinking "what can we do today to prevent a nuclear terrorist attack?" Keeping this issue on the front burner at the White House day-in and day-out will be crucial to success. The next U.S. president should also lean on Russia and other key countries to do the same.

Developing a comprehensive, prioritized plan. Today, the U.S. government has dozens of programs focused on pieces of the problem of preventing nuclear terrorism, each of which has its own plan for its own piece—and no comprehensive, prioritized plan. There is no systematic mechanism in place for identifying the top priorities or where there may be gaps, overlaps, or inefficiencies. One of the first priorities of the new senior official dedicated to preventing nuclear terrorism must be to put in place a comprehensive, prioritized plan—and then continuously modify it as circumstances change.

Assigning adequate resources. Nuclear security is affordable: a level of security that could greatly reduce the risk of nuclear theft could be achieved for all nuclear stockpiles worldwide for roughly one-percent of annual U.S. defense spending. The next U.S. president and the U.S. Congress should act to ensure that lack of money does not slow or constrain any major effort to keep nuclear weapons and the materials needed to make them out of terrorist hands. In particular, since new opportunities to improve nuclear security sometimes arise unexpectedly, and difficult-to-plan incentives are sometimes required to convince facilities to give up their HEU or convert a research reactor, Congress should consider an appropriation in the range of $500 million, to be available until expended, that can be spent flexibly on high-priority actions to reduce the risk of nuclear theft as they arise. Such a flexible pool of funds would give the new administration the ability to hit the ground running with an expanded and accelerated effort.

Providing information and analysis to support policy. Good information and analysis on where the greatest risks, opportunities, and obstacles to progress lie will be crucial to preventing nuclear terrorism. The next U.S. president should act to ensure that U.S. and international policies to reduce the risk of nuclear terrorism are informed by the best practicable information, from intelligence, other information collection, and analysis—including independent analysis and suggestions from non-government institutions. The highest-leverage area for information collection and analysis is likely to be supporting policy efforts to improve security for nuclear stockpiles—answering questions ranging from which sites have particularly large and vulnerable stockpiles, to which nuclear facilities have poorly paid staff or corrupt guards, to which research reactors are underutilized, underfunded, and might be convinced to shut down with a modest incentive package.

Putting the United States' own house in order

The most urgent nuclear security vulnerabilities are largely in other countries. But there is much more that can and should be done within the United States itself as well, as recent incidents in the U.S. Air Force make clear. Convincing foreign countries to reduce and consolidate nuclear stockpiles, to put stringent nuclear security measures in place, or to convert their research reactors from HEU to LEU fuel will be far more difficult if the United States is not doing the same at home. DOE should continue providing funding to convert U.S. research reactors to LEU. Congress should provide funding for DOE to help HEU-fueled research reactors, or research reactors that pose serious sabotage risks, to upgrade security voluntarily. At the same time, Congress should direct the Nuclear Regulatory Commission (NRC) to phase out the exemption from most security rules for HEU that research reactors now enjoy, and provide funding for DOE to help these reactors pay the costs of effective security. Congress should also insist that NRC revise its rule exempting HEU that is radioactive enough to cause doses of more than one Sievert per hour at one meter from almost all security requirements, as recent studies make clear that this level of radiation would pose little deterrent to theft by determined terrorists. The NRC's requirements for protection of potential nuclear bomb material should be strengthened to bring them roughly in line with DOE's rules for identical material (particularly since the NRC-regulated facilities handling this material are doing so mainly on contract to DOE in any case, so DOE will end up paying most of the costs of security as it does at its own sites). Congress should also provide incentives to convert HEU medical isotope production to LEU, without in any way interfering with supplies, by imposing a roughly 30 percent user fee on all medical isotopes made with HEU, with the funds used to help producers convert to LEU. This would give producers a strong financial incentive to convert, and since the isotopes are a tiny fraction of the costs of the medical procedures that use them, would not significantly affect the costs or availability of these life-saving procedures.

Finally, no matter what is done to prevent nuclear terrorism, it is essential that the United States get better prepared should such a catastrophe nevertheless occur. While some steps have been taken to prepare for the ghastly aftermath of a terrorist nuclear attack, a comprehensive plan and approach is needed. The United States needs a rapid ability to assess which people are in the greatest danger and to tell them what they can do to protect themselves. Better capabilities to communicate to everyone, when TV, radio, and cell phones in the affected area may not be functioning properly are also needed, as are much better public communication plans for the critical minutes and hours after such an attack. The U.S. government needs to do a much better job encouraging and helping people to take simple steps to get ready for an emergency. The United States also needs to put in place a better ability—including making use of the military's capabilities—to treat many thousands of injured people, along with more effective plans to keep the government and economy functioning while taking all the steps that will be needed to prevent another attack. (In particular, Congress has not yet acted to put a plan in place for reconstituting itself should most members of Congress be killed in a nuclear attack.) Many of these steps would help respond to any catastrophe, natural or man-made, and would pay off even if efforts to prevent a terrorist nuclear attack succeeded.

Coping with the danger of nuclear terrorism will pose a fundamental challenge for the next president and the next Congress. With a sensible strategy, adequate resources, and sustained leadership, the risk of nuclear terrorism can be dramatically reduced during the next president's first term. American security demands no less.

1 PREVENTING THE CATASTROPHE OF NUCLEAR TERRORISM

The U.S. president who takes office in January 2009 will face a world where the danger that terrorists could get and use a nuclear bomb remains very real. He will find that many steps have been taken to reduce the risk, particularly in the years since the 9/11 attacks, but that urgent actions are still needed to keep nuclear weapons and the materials needed to make them out of terrorist hands.

The purpose of this report—the seventh in an annual series—is to outline the danger of nuclear terrorism, to assess what has and has not been done to reduce it, and to suggest an agenda of actions that could dramatically reduce the risk during the next presidential term.[1] 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 stock of potential nuclear bomb material worldwide must be accounted for and secured, in ways that will last 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 dramatically.

[1] All of the reports in this series, and a wide array of other information on programs to secure, monitor, and reduce nuclear material stockpiles, are available at the "Securing the Bomb" section of the Nuclear Threat Initiative's website, at http://www.nti.org/securingthebomb. 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, eds., *The Four Faces of Nuclear Terrorism*, (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 28 March 2008). 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). For a less alarming look, see Michael Levi, *On Nuclear Terrorism* (Cambridge, Mass.: Harvard University Press, 2007). Another conceivable type of nuclear terrorism, not addressed here, is the possibility of terrorists somehow figuring out a way to cause an existing nuclear weapon to be launched, or to provoke existing nuclear weapon states to launch a nuclear attack (for example by introducing false alarms into nuclear warning systems). Possibly the earliest public discussion of such possibilities was in Bruce G. Blair and Gary D. Brewer, "The Terrorist Threat to the World's Nuclear Weapons Programs," *Journal of Conflict Resolution* Vol. 31, No. 3, September 1977, pp. 379-403, available at http://www.cdi.org/blair/terrorist-threat.cfm as of 30 October 2008. More recently, see, for example, Gary Ackerman and William C. Potter, "Catastrophic Nuclear Terrorism: A Preventable Peril," in Nick Bostrom and Milan M. Cirkovic, *Global Catastrophic Risks* (Oxford: Oxford University Press, 2008), pp. 402-449.

- **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 acquisition efforts should be put in place, including not only radiation detectors but also expanded international police and intelligence cooperation, increased emphasis on intelligence operations such as "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 nuclear programs in North Korea and Iran must be capped or rolled back, and 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.
- **Deter.** 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 knowingly provided by a state as an attack by that state, and will respond accordingly.
- **Impede.** The United States and other countries should make every effort to make it more difficult for terrorists to recruit experts who could help them with a nuclear plot, from providing alternative employment for key experts to countering the anti-American hatred that can contribute to such recruitment efforts.
- **Reduce.** The global stockpiles of nuclear weapons, separated plutonium, and HEU should be drastically reduced, and new production phased out.
- **Monitor.** Stockpiles of nuclear weapons, separated plutonium, and HEU—and reductions in these stockpiles—should increasingly come under international monitoring, facilitating cooperation in upgrading security and ensuring a baseline level of accounting for these dangerous stockpiles.

This report focuses primarily on the first two of these steps, for they offer the greatest available 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 a needle in a haystack.

This report is focused only on steps to prevent terrorist acquisition and use of an actual nuclear explosive. It does not cover the many additional steps needed to limit the spread of nuclear weapons to additional states,[2] or the broad range

[2] For a compilation of recommended steps for the broader problem of nuclear nonproliferation, see, for example, George Perkovich et al., *Universal Compliance: A Strategy for Nuclear Security* (Washington,

of non-nuclear means by which terrorists might be able to cause catastrophic harm.[3] The use of a nuclear bomb would be among the most difficult types of attack for terrorists to accomplish—but the massive, assured, instantaneous, and comprehensive destruction of life and property that would result may make nuclear weapons a priority for terrorists despite the difficulties.

Plan of the Report

This report proceeds as follows. The remainder of this chapter describes the continuing threat of nuclear terrorism—both the reasons to be concerned and the very real obstacles terrorists would face in attempting to commit such an atrocity. The next chapter assesses progress to date in reducing the risk—providing a qualitative overview of what has been done and what has not been done. Chapter 3 updates of a number of quantitative metrics that provide rough indicators of this progress. Chapter 4 analyzes the requested budgets for programs related to improving controls over nuclear weapons, materials, and expertise in countries around the world. Finally, Chapter 5 recommends further steps that should be taken to reduce the danger.

D.C.: Carnegie Endowment for International Peace, 2005; available at http://www.carnegieendowment.org/files/UC2.FINAL3.pdf as of 8 July 2008).

[3] For an official listing of major terrorist and natural scenarios that could cause catastrophic harm, see 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 28 March 2008).

The Continuing Threat of Nuclear Terrorism

The Lessons of Pelindaba

On the night of November 8, 2007, two teams of armed men attacked the Pelindaba nuclear facility in South Africa, where hundreds of kilograms of weapon-grade highly enriched uranium (HEU) are stored. One of the teams fired on the site security forces, who fled. The other team of four armed men disabled the detection systems at the site perimeter—possibly using insider knowledge of the security system—cut a hole in a 10,000-volt security fence, entered without setting off any alarm, broke into the emergency control center, and shot a worker there in the chest after a brief struggle. The worker at the emergency control center raised an alarm for the first time. These intruders spent 45 minutes inside the secured perimeter without ever being engaged by site security forces, and then disappeared through the same hole they had cut in the fence. No one on either team was shot or captured. South African officials later arrested three individuals, but soon released them without charge, suggesting that they were not among the four who penetrated the site that night.[4] The security manager and several of the guards on duty were subsequently fired. The South African government has not released important details of its investigation of the attack and refused earlier U.S. offers to remove

[4] Micah Zenko, "A Nuclear Site is Breached: South African Attack Should Sound Alarms," *Washington Post,* 20 December 2007. See also Rob Adam, "Media Briefing: Security Breach at Necsa on 08 November 2007," Nuclear Energy Corporation of South Africa, 13 November 2007; Graeme Hosken, "Officer Shot as Gunmen Attack Pelindaba," *Pretoria News,* 9 November 2007; Hosken, "Two Gangs of Armed Men Breach Pelindaba Nuclear Facility," *Pretoria News,* 14 November 2007; Joel Avni, Gertrude Makhafola, and Sibongile Mashaba, "Raid on Site Planned," *The Sowetan,* 14 November 2007.

the HEU at Pelindaba or to help improve security at the facility. Indeed, South Africa has delayed for years in establishing and implementing a specific requirement that the site be able to defend against a defined set of potential attacker capabilities, known as a design basis threat (DBT), as recommended by the IAEA. As of the time of the attack, South African security regulations did not yet include a DBT.[5]

While there is no publicly available evidence that these attackers were after the HEU, this incident is nevertheless a potent reminder that inadequately secured nuclear material is a global problem, not one limited to the former Soviet Union. The Pelindaba break-in leads to one inescapable conclusion: the world urgently needs a global campaign to ensure that every nuclear weapon and every stock of potential nuclear bomb material worldwide is secured against the kinds of threats terrorists and criminals have demonstrated they can pose—including two teams of armed attackers, possibly with cooperation from an insider. But given the South African refusal to accept nuclear security assistance or to allow the HEU to be removed in the years leading up to the attack, the incident is also a reminder that political heavy lifting will be needed to overcome the serious obstacles to sensitive nuclear security cooperation around the world.

Nuclear Terrorism Risks: The Bad News

The answers to several basic questions can provide a more detailed understanding of the risk of nuclear terrorism.

Do terrorists want nuclear weapons? For most terrorists, focused on small-scale violence to attain local objectives, the answer is "no." But for a small set of terrorists, the answer is clearly "yes." Osama bin Laden has called the acquisition of nuclear weapons or other weapons of mass destruction a "religious duty."[6] Al-Qaeda operatives have made repeated attempts to buy nuclear material for a nuclear bomb, or to recruit nuclear expertise—including the two extremist Pakistani nuclear weapon scientists who met with bin Laden and Ayman al-Zawahiri to discuss nuclear weapons. For years, al-Qaeda operatives have repeatedly expressed the desire to inflict a "Hiroshima" on the United States.[7] Before al-Qaeda, the Japanese terror cult Aum Shinrikyo also made a concerted effort to get nuclear weapons.[8] With at least two groups going

[5] In the annual report for the period leading up to the break-in, the South African department that oversees the site acknowledged that goal of "implementation of a revised nuclear security framework" was "0 percent complete", because "Design Basis Threat (DBT) document not yet established." See Department of Minerals and Energy, Annual Report 2006/2007 (Johannesburg: DME, 2007), p. 69. This report was briefed to the parliament the week after the break-in, but the subject of security was not mentioned. Similarly, the South African nuclear regulator testified on his annual report two weeks after the break-in, and pronounced himself "generally happy" with security at Pelindaba, though the fact that the assailants had disabled the systems designed to report either intrusions or tampering with the system was "very worrying." See hearing notes by the Parliamentary Monitoring Group, available as of 1 June 2008 at http://www.pmg.org.za/minutes/20071120-national-nuclear-regulator-annual-report-200607-briefing.

[6] 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 27 March 2008).

[7] Steve Coll, "What Bin Laden Sees in Hiroshima," *Washington Post*, 6 February 2005.

[8] For discussion of the al-Qaeda and Aum Shinrikyo efforts, see 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 27 March 2008); Sara Daly, John Parachini, and

down this path in the last 15 years, there is no reason to expect that others will not do so in the future.

Rolf Mowatt-Larssen, head of intelligence for the U.S. Department of Energy (DOE), testified to the U.S. Senate in the spring of 2008 that "al-Qaida's nuclear intent remains clear," citing, among other things, bin Laden's successful effort, in 2003, to get a radical Saudi cleric to issue a religious ruling, or *fatwa*, authorizing the use of nuclear weapons on American civilians.[9] Mowatt-Larssen warned that the world's efforts to prevent terrorists from gaining the ability "to develop and detonate a nuclear weapon" are likely to be "tested" in "the early years of the 21st century."[10]

In the spring of 2008, websites catering to violent Islamic extremists began "buzzing," in the words of one well-informed analyst of al-Qaeda-linked terrorists, "with talk about an impending AQ [al-Qaeda] nuclear attack on the U.S."[11] This culminated in the release of a video in late May 2008, "The Prayer, The Prayer (Answered)–Allah Akbar America Has Been Destroyed–By a Fatal Jihadi Nuclear Strike."[12] The FBI had sent out a bulletin to thousands of law enforcement officials around the United States warning of the video's imminent release.[13]

Of course, terrorists make such statements precisely to generate fear, and they should not be taken at face value. The recent video and chatter came from al-Qaeda supporters, not from people directly connected to al-Qaeda's central organization. As such, they should not be taken as an al-Qaeda statement of intent to carry out a nuclear attack in the near term. Still less should they be considered proof of al-Qaeda nuclear capability.[14] What is terrifying is that no one outside al-Qaeda knows what real capabilities some secret cell may be silently working to put together.

Nevertheless, this upsurge in nuclear chatter is worrisome, for it conforms

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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 28 March 2008). For further details on U.S. intelligence on some of al-Qaeda's nuclear efforts, see George Tenet, *At the Center of the Storm: My Years at the CIA* (New York: HarperCollins, 2007); 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 25 June 2008).

[9] For an English translation of this fatwa, see Nasir Bin Hamd al-Fahd, "A Treatise on the Legal Status of Using Weapons of Mass Destruction Against Infidels," May 2003, available at http://www.carnegieendowment.org/static/npp/fatwa.pdf as of 8 August 2008. Al-Fahd has since been arrested, and has publicly renounced some of his previous rulings, including this one.

[10] Rolf Mowatt-Larssen, testimony to the Committee on Homeland Security and Governmental Affairs, U.S. Senate, 2 April 2008. Before taking over as head of DOE intelligence, Mowatt-Larssen led the Central Intelligence Agency's efforts to track al-Qaeda's weapons of mass destruction programs. Mowatt-Larssen now chairs an intelligence-community-wide working group on nuclear terrorism.

[11] See William McCants, "Going Nuclear," 27 May 2008, available at http://www.jihadica.com/going-nuclear/ as of 2 June 2008.

[12] The video was posted on the "Ekhlass" forum on 25 May 2008. See discussion in William McCants, "Insider Analysis of Nuke Tape," 30 May 2008, available at http://www.jihadica.com/insider-analysis-of-nuke-tape/ as of 2 June 2008.

[13] Pierre Thomas and Theresa Cook, "Al-Qaeda Supporters' Tape to Call for Use of WMDs," *ABC News.com*, 27 May 2008.

[14] See McCants, "Going Nuclear"; McCants, "No Nuke Chatter?" 28 May 2008; and McCants, "Insider Analysis of Nuke Tape," all available at http://www.jihadica.com as of 2 June 2008.

with the consistent message of the last decade—that at least some factions of violent Islamic extremists would dearly love to get a nuclear bomb and use it against the West. The broader the community of extremists that supports escalating to the nuclear level of violence, the more likely it is that al-Qaeda will succeed in recruiting nuclear guards, nuclear physicists, uranium metallurgists, and others who could help the group fulfill its nuclear ambitions.

Is it plausible that a sophisticated terrorist group could make a crude nuclear bomb if it got HEU or separated plutonium? The answer here is also "yes." Making at least a crude nuclear bomb might well be within the capabilities of a sophisticated group, though a nuclear bomb effort would be the most technically challenging operation any terrorist group has ever accomplished. 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."[15] Indeed, even before the revelations from Afghanistan, 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."[16]

A terrorist cell of relatively modest size, with no large fixed facilities that would draw attention, might well be able to pull off such an effort—and the world might never know until it was too late.[17] Mowatt-Larssen told Congress that an al-Qaeda nuclear bomb effort "probably would not require the involvement of more than the number of operatives who carried out 9/11," and would be "just as compartmented," making it extraordinarily difficult for the intelligence community to detect and stop.[18]

Al-Qaeda's nuclear efforts in Afghanistan were disrupted when the Taliban regime was overthrown. But al-Qaeda has been reconstituting its ability to plan and direct large complex operations from the tribal areas of Pakistan. As Director of National Intelligence (DNI) Michael McConnell told the Senate in February, 2008:[19]

> Al-Qa'ida's top leaders Usama Bin Ladin and Ayman al-Zawahiri continue to be able to maintain al-Qa'ida's unity and its focus on their strategic vision of confronting our allies and us with mass casualty attacks around the globe… al-Qa'ida and other terrorist

[15] U.S. Congress, Office of Technology Assessment, *Nuclear Proliferation and Safeguards* (Washington, D.C.: OTA, 1977; available at http://www.princeton.edu/~ota/disk3/1977/7705/7705.PDF as of 27 March 2008), p. 140. OTA reached this conclusion long before the internet made a great deal of relevant information much more widely available.

[16] Commission on the Intelligence Capabilities of the United States Regarding Weapons of Mass Destruction, *Report to the President*, p. 276.

[17] For discussions of official assessments of the complexity of the operation and the number of people required, 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). 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.

[18] Mowatt-Larssen, 2 April 2008 testimony to the Committee on Homeland Security and Governmental Affairs.

[19] DNI Michael McConnell, "Annual Threat Assessment of the Intelligence Community," testimony to the Committee on Armed Services, U.S. Senate, 27 February 2008.

> groups are attempting to acquire chemical, biological, radiological, and nuclear weapons and materials (CBRN). We assess al-Qa'ida will continue to try to acquire and employ these weapons and materials…

No one knows for sure what the current status of al-Qaeda's nuclear effort is—or how much they may have learned from past failures that may increase their chance of future success.[20] But if they could get the needed HEU or plutonium, there is no basis for confidence that they could not put together and deliver a crude but devastating nuclear bomb.

Could a terrorist group plausibly get the material needed for a nuclear bomb? Unfortunately, the answer here is also "yes." Nuclear weapons or their essential ingredients exist in hundreds of buildings in dozens of countries. Security measures for many of these stocks are excellent—but security for others is appalling, in some cases amounting to no more than a night watchman and a chain-link fence. No specific and binding global standards for how these stockpiles should be secured exist.

The risk of nuclear theft from any particular facility or transport operation depends on the quantity and quality of the material available to be stolen (that is, its suitability for use in a nuclear bomb), the security measures in place (that is, what kind of insider and outsider thieves could the security measures protect against, with what probability), and the threats those security measures face (that is, the probability of different levels of insider or outsider capabilities being brought to bear in a theft attempt). Based on the limited unclassified information available, it appears that the highest risks of nuclear theft today are in Russia, Pakistan, and at HEU-fueled research reactors around the world.

Russia. Nuclear security in Russia and the former Soviet Union has improved dramatically in the past 15 years; at many sites, the difference between the security in place today and the security in place in 1994 is like night and day. (Progress and steps still to be taken in improving nuclear security in Russia are discussed in more detail in the next chapter.) But Russia has the world's largest stockpiles of nuclear weapons and materials, scattered in the world's largest number of buildings and bunkers; some serious security weaknesses still remain, ranging from poorly trained, sometimes suicidal guards to serious under-funding of nuclear security; and the upgraded security systems must face huge threats, from insider theft conspiracies which are cropping up everywhere in Russia to large-scale outsider attacks. Since 9/11, in Russia, terrorist reconnaissance teams have carried out reconnaissance at secret nuclear weapon storage sites;[21] a Russian court case revealed that a Russian businessman had been offering $750,000 for stolen weapon-

[20] For a discussion of both the possibility that multiple terrorist failures may contribute to eventual success, and the difficulty that insular terrorist groups have in changing their approaches (and replacing ineffective experts), see Richard Danzig, "Limitations of Terrorists…and Ourselves," presentation to "Pivot Point: New Directions for American Security," Center for a New American Security, Washington, D.C., 11 June 2008.

[21] 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," *Associated Press*, 25 October 2001; Pavel Koryashkin, "Russian Nuclear Ammunition Depots Well Protected—Official," *ITAR-TASS*, 25 October 2001. 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.

grade plutonium;[22] and the Beslan school massacre confirmed the terrorists' ability to strike in force, without warning or mercy. As just one indicator of the insider threat, in 2006 President Putin fired Major General Sergey Shlyapuzhnikov, deputy chairman of the section of the Ministry of Internal Affairs (Russian acronym MVD) responsible for guarding the closed nuclear cities and other closed territories, because (according to the Russian state newspaper), he was helping to organize smuggling in and out of these closed territories—in particular, giving out passes that allowed people and vehicles to go in and out without being checked.[23]

Pakistan. Pakistan's nuclear stockpile is small, stored at a small number of sites, and is thought to be heavily guarded, with substantial security upgrades in recent years, in part with U.S. help.[24] In February 2008, DNI McConnell testified that the U.S. intelligence community's assessment was that the Pakistani Army's ability to secure Pakistan's nuclear stockpiles "has not been degraded by Pakistan's political crisis."[25] But Pakistani security systems face immense threats, from nuclear insiders, some of whom have a demonstrated willingness to sell practically anything to practically anybody, to armed attack potentially by scores or hundreds of jihadis. In at least two cases, serving Pakistani military officers working with al-Qaeda came within a hair's breadth of assassinating former president Musharraf.[26] If the military officers guarding the President cannot be trusted, how much confidence can the world have in the military officers guarding the nuclear weapons?

HEU-fueled research reactors. HEU-fueled research reactors typically have comparatively modest stockpiles of material—but they have some of the world's weakest security measures for those stocks. (Ironically, the security measures at Pelindaba are more substantial than they are at many HEU-fueled research reactors around the world.) And it is important to remember that much of the irradiated fuel from research reactors is still HEU, and is not radioactive enough to pose any significant deterrent to theft by suicidal terrorists.[27] As dis-

[22] 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 18 June 2008). See also "Russian Court Sentences Men for Weapons-Grade Plutonium Scam," trans. BBC Monitoring Service, *RIA Novosti*, 14 October 2003; "Russia: Criminals Indicted for Selling Mercury as Weapons-Grade Plutonium," trans. U.S. Department of Commerce, *Izvestiya*, 11 October 2003.

[23] "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*, 2 June 2006 [translated by Anatoly Dianov].

[24] 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); and Kenneth N. Luongo and Brig. Gen. (Ret.) Naeem Salik, "Building Confidence in Pakistan's Nuclear Security," *Arms Control Today,* December 2007.

[25] McConnell, "Annual Threat Assessment," 27 February 2008.

[26] "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.

[27] For a discussion of the proliferation threat posed by irradiated HEU fuel, see Matthew Bunn and

cussed in detail in the next chapter, some 130 research reactors around the world still use HEU as their fuel. Many tons of HEU exist at these research reactors.[28] Often—though not always—this material is in forms that would require some chemical processing to use in a bomb. But any group that could pull off the difficult job of making a nuclear bomb from HEU metal would have a good chance of mastering the simpler job of getting HEU metal out of research reactor fuel.

Other risks. While these are the highest-risk categories, there are others where the risks are very real. Transport of nuclear weapons and materials is a particular concern, as it is the part of the nuclear material life-cycle most vulnerable to violent, forcible theft, since it is impossible to protect the material with thick walls and many minutes of delay when it is on the road, and transports of both weapons and materials are remarkably frequent.[29] In the end, virtually every country where these materials exist—including the United States—has more to do to ensure that these stocks are effectively protected against the kinds of threats that terrorists and criminals have shown they can pose.

Confirmed thefts. Theft of HEU and plutonium is not a hypothetical worry, it is an ongoing reality. Most recently, in February 2006, Russian citizen Oleg Khinsagov was arrested in Georgia (along with three Georgian accomplices) with some 100 grams of 89 percent enriched HEU, claiming that he had kilograms more available for sale.[30] The IAEA has confirmed 18

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. 36-37. For studies of the fact that a radiation level from irradiated fuel of 100 rad/hr at one meter is grossly insufficient to prevent theft by determined terrorists, 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 (Washington, D.C.: U.S. Nuclear Regulatory Commission, 1982; available at http://www.sciencemadness.org/lanl1_a/lib-www/la-pubs/00307470.pdf as of 28 March 2008); 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).

[28] Throughout this report, "tons" refers to metric tons. Each metric ton equals 1000 kilograms, or just over 2200 pounds.

[29] For a critical review of transport security in France, in particular, see Ronald E. Timm, *Security Assessment Report for Plutonium Transport in France* (Paris: Greenpeace International, 2005; available at www.greenpeace.fr/stop-plutonium/en/TimmReportV5.pdf as of 18 June 2008). In France, long-distance transports of large quantities of separated plutonium are a weekly occurrence 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). In Russia, the U.S. Nunn-Lugar program sponsors warhead shipments from deployment sites back to storage or dismantlement sites, and these shipments alone occur almost weekly. U.S. Department of Defense, *Cooperative Threat Reduction Annual Report to Congress: Fiscal Year 2009* (Washington, D.C.: U.S. Department of Defense, 2008, p. 2 and p. 14). Tens of tons of HEU are sent in dozens of shipments over thousands of kilometers of rail in Russia every year. U.S. Congress, General Accounting Office, *Status of Transparency Measures for U.S. Purchase of Russian Highly Enriched Uranium* (Washington, D.C.: GAO, 1999; available at http://www.gao.gov/archive/1999/rc99194.pdf as of 10 July 2007). In the United States, the "Secure Transportation Asset" program of the Department of Energy, which transports both nuclear weapons and weapons-usable nuclear material, carries out roughly 100 shipments every year—approximately two a week. U.S. Department of Energy, *FY 2009 Congressional Budget Request: National Nuclear Security Administration*, DOE/CF-024 Vol. 1 (Washington, DC: DOE, February 2008), p. 313.

[30] For an especially useful account of this case, see Michael Bronner, "100 Grams (And Counting): Notes From the Nuclear Underworld" (Cambridge, Mass.: Project on Managing the

incidents of theft or loss of HEU or separated plutonium.[31] Other incidents are known to have occurred—the thieves were captured, tried, and convicted—but have nevertheless not been confirmed by the states concerned.[32] What we do not know, of course, is how many thefts may have occurred that were never detected; it is a sobering fact that nearly all of the stolen HEU and plutonium that has been seized over the years had never been missed when it was originally stolen.[33]

The amounts required for a bomb are small. The Nagasaki bomb included some 6 kilograms of plutonium, which would fit easily in a soda can. A similar HEU bomb would require three times as much.[34] For a simpler but less efficient gun-type design, roughly 50 kilograms of HEU would be needed—an amount that would fit easily into two two-liter bottles. The world stockpiles of HEU and separated plutonium are enough to make roughly 200,000 nuclear weapons;[35] a tiny fraction of one

Atom, Harvard University, June 2008, available at http://belfercenter.ksg.harvard.edu/publication/18361/100_grams_and_counting.html as of 11 November 2008). See also Laurence Scott Sheets, "A Smuggler's Story," *Atlantic Monthly,* April 2008, and 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 18 June 2008).

[31] For the International Atomic Energy Agency's most recent list of incidents confirmed by the states concerned, see *Incidents Involving HEU and Pu Confirmed to the ITDB, 1993-2006* (Vienna: IAEA, 2007, available as of 28 March 2008 at http://www.iaea.org/NewsCenter/Focus/NuclearSecurity/pdf/heu-pu_1993-2006.pdf). There are 18 total incidents on this list, but three of them appear to involve inadvertent losses rather than thefts. Some incidents that were previously on the list have been removed: 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.)

[32] Perhaps the best summary of the available data on 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), pp. 119-138. (Lyudmila Zaitseva, principal author.)

[33] 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." 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 28 March 2007). 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. 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 28 March 2008). 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 28 March 2007).

[34] The Department of Energy has officially declassified the fact that 4 kilograms of plutonium is in principle sufficient to make a nuclear weapon. U.S. Department of Energy, *Restricted Data Declassification Decisions 1946 to the Present (RDD-7)* (Washington, D.C.: DOE, 2001; available at http://www.fas.org/sgp/othergov/doe/rdd-7.html as of 27 March 2008). The amount of plutonium in the first nuclear bomb, at Trinity, was 6.1 kilograms. See Gen. Leslie R. Groves, Memorandum to the Secretary of War, 18 July 1945, reprinted as Appendix P in Martin Sherwin, *A World Destroyed* (New York: Knopf, 1975). The bare-sphere critical mass for 93 percent HEU metal is roughly three times the bare-sphere critical mass for delta-phase weapon-grade plutonium.

[35] The world stockpile of separated plutonium is roughly 500 metric tons (roughly half civilian and half military); the world stockpile of HEU is in the range of 1,400-2,000 tons (all but a few percent

percent of these stockpiles going missing could cause a global catastrophe.

Could a terrorist group deliver a bomb to Washington, New York, or other major cities around the world? Here, too, unfortunately, the answer is "yes," they probably could. If stolen or built abroad, a nuclear bomb might be delivered to the United States, intact or in ready-to-assemble pieces, by boat or aircraft or truck. The length of the border, the diversity of means of transport, the vast scale of legitimate traffic across national borders, and the ease of shielding the radiation from plutonium or especially from HEU all operate in favor of the terrorists. Building the overall system of legal infrastructure, intelligence, law enforcement, border and customs forces, and radiation detectors needed to find and recover stolen nuclear weapons or materials, or to interdict these as they cross national borders, is an extraordinarily difficult challenge.[36]

What would happen if terrorists set off a nuclear bomb in a U.S. city? Here, the answers are nothing short of terrifying.[37] 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 roughly $1 trillion in direct economic damage.[38] No capability is yet available to provide medical care for hundreds of thousands of burned, injured, and irradiated people in any reasonable period of time.[39] Terrorists—either those who

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of which is military). See International Panel on Fissile Materials, *Global Fissile Material Report 2007* (Princeton: IPFM, 2007, available as of 28 March 2008 at http://www.fissilematerials.org/ipfm/site_down/gfmr07.pdf). The separated plutonium total includes both weapon-grade and reactor-grade plutonium. Reactor-grade plutonium is also weapons-usable. For a detailed unclassified official statement on this point 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 13 May 2008), pp. 37-39.

[36] For a useful discussion emphasizing the ease with which terrorists might follow different pathways to deliver their weapon, see Allison, *Nuclear Terrorism: The Ultimate Preventable Catastrophe*. For a more optimistic view of the potential of these parts of a defensive system, see Levi, *On Nuclear Terrorism*.

[37] For an excellent overview of the demands of "The Day After" such an attack, see 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* (Cambridge, Mass.: Preventive Defense Project, Harvard and Stanford Universities, 2007; available at http://belfercenter.ksg.harvard.edu/publication/2140/ as of 18 June 2008).

[38] 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 28 March 2008), 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*. Recent detailed non-government analyses include 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 28 March 2008); 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 28 March 2008).

[39] See, for example, Irwin Redlener, "Survival in the Nuclear Gray Zone: Why We Have Not Addressed Response Planning for Nuclear Terrorism—and

committed the attack or others—would probably claim they had more bombs already hidden in U.S. cities (whether they did nor 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. If the bomb went off in Washington D.C., large fractions of the federal government would be destroyed, and effective governance of the country would be sorely tested, despite current planning for continuity of government. Given the horror of the attack, fears that more were coming, and the possibility that the essential ingredients of a nuclear bomb could fit in a suitcase, it is very likely that traditional notions of civil liberties and protection against unreasonable search and seizure would fall by the wayside. Devastating economic aftershocks would reverberate throughout the country and the world—global effects that in 2005 then-UN Secretary-General, Kofi Annan warned would push "tens of millions of people into dire poverty," creating "a second death toll throughout the developing world."[40] America and the world would be transformed forever—and not for the better.[41]

Why We Must," testimony to the Committee on Homeland Security and Governmental Affairs, U.S. Senate, 15 May 2008, available at http://hsgac.senate.gov/public/_files/051508Redlener.pdf as of 3 June 2008. Redlener is the director of the National Center for Disaster Preparedness at the Columbia University Mailman School of Public Health.

[40] 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 18 June 2008).

[41] For a meditation arguing 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. Former Undersecretary of Defense for Policy Fred Iklé has gone so far as to describe the threat as "annihilation from within." See Fred Charles Iklé, *Annihilation From Within: The Ultimate Threat to Nations* (New York: Columbia University Press, 2006), 160 p.

Nuclear Terrorism Risks: The Good News

Fortunately, there is good news in this story as well. First, there is no convincing evidence that any terrorist group has yet gotten a nuclear weapon or the materials needed to make one—or that al-Qaeda has yet put together the expertise that would be needed to make a bomb. Indeed, there is some evidence of confusion and lack of nuclear knowledge by some senior al-Qaeda operatives.[42]

Second, making and delivering even a crude nuclear bomb would be the most technically challenging and complex operation any terrorist group has ever carried out. There would be many chances for the effort to fail, and the cumulative obstacles may seem daunting even to determined terrorists, leading them to focus more of their efforts on conventional tools of terror—as al-Qaeda appears to have done.[43] Both al-Qaeda and Aum Shinrikyo appear to have encountered a variety of difficulties, demonstrating that getting a nuclear bomb is a difficult challenge, even for large and well-financed terrorist groups with ample technical resources.[44]

Third, the overthrow of the Taliban and the disruption of al-Qaeda's old central

[42] In particular, both Khalid Sheikh Mohammed and Abu Zubaydah are reported to have believed that uranium, which is only weakly radioactive, would be a good material for a dirty bomb—and there have been other al-Qaeda operatives arrested for seeking uranium for dirty bombs as well. See discussion and sources in Bunn and Wier, "The Demand for Black Market Fissile Material."

[43] For the most comprehensive available account of this argument, see Levi, *On Nuclear Terrorism*.

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

command structure certainly reduced al-Qaeda's chances of pulling off such a complex operation—though that capability may be growing again, as al-Qaeda reconstitutes in the mountains of Pakistan.[45]

Fourth, there is now a very real debate even among the community of violent Islamic extremists over the moral legitimacy of the mass slaughter of innocents. One of the founders of al-Qaeda, who wrote two of the books that al-Qaeda has long relied on for its ideological justification for violent jihad, has written a new book which argues that most forms of terrorism—and particularly indiscriminate killing of bystanders—are forbidden by Islamic law, and that violent jihad is only permissible under very rare circumstances. "There is nothing that invokes the anger of God and His wrath like the unwarranted spilling of blood and wrecking of property," he argues.[46] Al-Qaeda was sufficiently concerned over this frontal assault by one of its founders that Ayman al-Zawahiri rushed out a 188-page response only two months after the book was released. Moreover, when al-Qaeda organized an electronic question-and-answer session with Zawahiri, many of the questions Zawahiri chose to answer focused on bitter criticisms of al-Qaeda's killing of innocent people, and Zawahiri was at pains to argue that al-Qaeda fighters would kill innocents only when doing so was unavoidable, quoting bin Laden as instructing al-Qaeda's fighters to "make sure that their operations targeting the enemies are regulated by the regulations of the Shari'ah and as far as possible from Muslims."[47] A nuclear bomb, of course, is the apotheosis of indiscriminate mass slaughter, making no distinction between the innocent and the guilty, between Muslims and non-Muslims. These dissents are not likely to convince bin Laden and Zawahiri, but the more the broader community of extreme Islamists comes to view the nuclear level of mass slaughter as a moral crime, the more difficult it is likely to be for al-Qaeda to recruit experts to help them build a nuclear bomb.

Fifth, as discussed in detail in the next chapter, nuclear security is improving. While there is a great deal yet to be done, the fact is that at scores of sites in Russia, the former Soviet Union, and elsewhere, security is dramatically better than it was fifteen years ago. Security upgrades are scheduled to be completed for most Russian nuclear warhead and nuclear material sites by the end of 2008. HEU is being removed from sites all around the world, permanently eliminating the risk of nuclear theft at those sites. An alphabet soup of programs and initiatives—Cooperative Threat Reduction (CTR), the Materials Protection, Control, and Accounting (MPC&A) program, the Global Threat Reduction Initiative (GTRI), the Global Initiative to Combat Nuclear Terrorism (GI), the International Atomic Energy Agency's Office of Nuclear Security, the Domestic Nuclear Detection Office (DNDO), and many more—are each making real contributions. There can be no doubt that America and the world face a far lower risk of nuclear terrorism today than they would have faced had these efforts never been begun. These programs

[45] McConnell, "Annual Threat Assessment," 27 February 2008. See also 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).

[46] The new book is from Sayyid Imam al-Sharif, sometimes known as "Dr. Fadl," an original member of the al-Qaeda ruling council. See Lawrence Wright, "The Rebellion Within," *The New Yorker,* 2 June 2008, pp. 37-53.

[47] "The Open Meeting with Shaykh Ayman al-Zawahiri," As-Sahab Media, 1429-2008. As-Sahab is al-Qaeda's media arm.

are excellent investments in U.S. and world security, deserving strong support; Americans and the world owe a substantial debt of gratitude to the dedicated U.S., Russian, and international experts who have been carrying them out. Securing the world's stockpiles of nuclear weapons and the materials needed to make them is a big job, and a complex job, but it is a doable one, as the progress already made demonstrates.

Sixth, hostile states are highly unlikely to consciously choose to provide nuclear weapons or the materials needed to make them to terrorist groups. Such a decision would mean transferring the most awesome military power the state had ever acquired to a group over which it has little control, and potentially opening the regime to overwhelming retaliation—a particularly unlikely step for dictators or oligarchs obsessed with controlling their states and maintaining power.[48]

All of this good news comes with a crucial caveat: "as far as we know." The gaps in our knowledge remain wide. Some intelligence analysts argue that the lack of hard evidence of an extensive current al-Qaeda nuclear effort simply reflects al-Qaeda's success in compartmentalizing the work and keeping it secret. It is a sobering thought that a nuclear effort might not require a conspiracy larger than the one which perpetrated the 9/11 attacks, which succeeded in remaining secret—and that Aum Shinrikyo was simply not on the radar of any of the world's intelligence agencies until *after* they perpetrated their nerve gas attack in the Tokyo subways.

[48] See, for example, Bunn, Wier, and Holdren, *Controlling Nuclear Warheads and Materials*, pp. 22-23; Matthew Bunn, "A Mathematical Model of the Risk of Nuclear Terrorism," *Annals of the American Academy of Political and Social Science* 607 (September 2006).

Nuclear Terrorism: What is the Probability?

So, taking the good news with the bad, what are the chances of a terrorist nuclear attack? The short answer is that nobody knows. Former Secretary of Defense William Perry and former Assistant Secretary of Defense Graham Allison are among those who have estimated that chance at more than 50 percent over the next ten years.[49] In a 2006 article, I offered a mathematical model that provides a structured, step-by-step way of thinking through the problem. A set of plausible illustrative values for the input parameters resulted in a 29 percent 10-year probability estimate—by coincidence, the same as the median estimate of the 10-year probability of a nuclear attack on the United States in a survey of national security experts by Senator Lugar's office some years ago.[50] Since there are large uncertainties in each of those inputs, however, the real probability could well be either higher or lower. But even if such estimates are too high by a factor of ten, the danger of nuclear terrorism is high enough to significantly increase the yearly risk of death for everyone who lives and works in downtown Washington or midtown Manhattan, where such a strike is most likely to occur.

Even a 1 percent chance over the next ten years would be enough to justify substantial action to reduce the risk, given the

[49] See, for example, Allison, *Nuclear Terrorism: The Ultimate Preventable Catastrophe*. For a report of Perry's estimate, see Nicholas D. Kristof, "An American Hiroshima," *New York Times*, 11 August 2004 available at http://query.nytimes.com/gst/fullpage.html?res=9502E7DC1F3CF932A2575BC0A9629C8B63 as of 11 November 2008.

[50] See Bunn, "A Mathematical Model." The responses to Lugar's queries are in 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 8 July 2008).

scale of the consequences. No one in their right mind would operate a nuclear power plant upwind of a major city that had a 1 percent chance over ten years of blowing sky-high—the risk would be understood by all to be too great. But that, in effect, is what we are doing—or worse—by managing the world's nuclear stockpiles as we do today. The nuclear security improvements and nuclear material removals that have been accomplished in recent years—along with the disruption of al-Qaeda's central command—have reduced the risk. But the danger remains very real.

2 PROGRESS IN REDUCING THE RISK OF NUCLEAR THEFT AND TERRORISM: A QUALITATIVE ASSESSMENT

On 5 June 2008, U.S. Secretary of Defense Robert Gates announced that he had asked for the resignations of the Secretary of the Air Force and the Air Force Chief of Staff over inadequate Air Force leadership of security and control of nuclear weapons.[1] The resignations followed a case in August 2007 in which a B-52 bomber had been inadvertently loaded with nuclear warheads and flown from North Dakota to Louisiana, with no one noticing the weapons were on the bomber for some 36 hours, and another incident in which the United States inadvertently shipped radar fuses for U.S. nuclear missiles to Taiwan, and did not notice the error for some 18 months.[2]

Investigations found a long-term decline in the Air Force's focus on providing appropriate controls for nuclear weapons, and reportedly concluded that as many as 1,000 sensitive nuclear weapons components are unaccounted for.[3] Reviews also concluded that "most sites" where U.S. nuclear weapons were stored in Europe would need "significant additional resources" to meet Department of Defense (DOD) security requirements.[4] And despite months of preparation, the unit involved in the B-52 incident received an "unacceptable" rating for security for nuclear weapons in an inspection in May 2008, with one nuclear weapons guard reportedly playing video games on his cell phone while on duty.[5]

"Mistakes are not acceptable when shipping and controlling" nuclear weapons and classified parts of nuclear weapons systems, Gates said, pledging that the United States would maintain "complete physical control of nuclear weapons" and would "properly handle the associated components at all times."[6] Gates has appointed a high-level panel under former Secretary of Defense James Schlesinger to recommend steps to improve nuclear security.

[1] See, for example, Thom Shanker, "2 Leaders Ousted From Air Force in Atomic Errors," *New York Times,* 6 June 2008 available at http://www.nytimes.com/2008/06/06/washington/06military.html as of 11 November 2008.

[2] A detailed account of the inadvertent movement of the six nuclear weapons, along with a review of organizational issues that contributed to this incident, can be found in DSB, Permanent Task Force on Nuclear Weapons Surety, *Report on the Unauthorized Movement of Nuclear Weapons* (Washington, D.C.: U.S. Department of Defense, February 2008, available at http://www.fas.org/nuke/guide/usa/doctrine/usaf/Minot_DSB-0208.pdf as of 22 June 2008). For the Taiwan episode, see, for example, Josh White, "Nuclear Parts Sent to Taiwan in Error," *Washington Post,* 26 March 2008, p. A1.

[3] See, for example, DSB, *Report on the Unauthorized Movement of Nuclear Weapons*; Major General Polly A. Peyer, chair, *Air Force Blue Ribbon Review of Nuclear Weapons Policies and Procedures* (Washington, D.C.: U.S. Air Force, 8 February 2008, available at http://www.fas.org/nuke/guide/usa/doctrine/usaf/BRR-2008.pdf as of 22 June 2008); and Demetri Sevastopulo, "U.S. N-Weapons Parts Missing, Pentagon Says," *Financial Times,* 19 June 2008, p. 8.

[4] See, for example, Hans Kristensen, "USAF Report: 'Most' Nuclear Weapon Sites in Europe Do Not Meet Security Requirements," *FAS Strategic Security Blog,* 19 June 2008, describing portions of Peyer, *Air Force Blue Ribbon Review of Nuclear Weapons Policies and Procedures*. Kristensen has played a critical role in bringing this report and others on related topics to light and analyzing the key issues they raise.

[5] Walter Pincus, "Air Force Unit's Nuclear Weapons Security is 'Unacceptable'," *Washington Post,* 31 May 2008, p A3.

[6] Shanker, "2 Leaders Ousted From Air Force in Atomic Errors."

These events make clear that even in the United States, which spends more on nuclear security than any other country, and has often taken the lead in efforts to improve nuclear security around the world, there is more to be done to ensure that all nuclear weapons and materials are effectively accounted for and secured.[7] Effective nuclear security requires eternal vigilance; without a constant struggle to improve, a slow decline in security is the almost inevitable result. Unfortunately, in many other countries, there is far less evidence of such vigilance than there is in the United States.

Today, planned U.S.-funded security and accounting upgrades for buildings with nuclear material and sites with nuclear warheads in Russia and the other states of the former Soviet Union are nearing completion (as described in detail below). These upgrades are greatly reducing the risk of nuclear theft, representing a major improvement in U.S. and world security. But they are not the end of the nuclear security story. The most important nuclear security policy issues today have to do with what else needs to be done—consolidating nuclear weapons and materials in fewer locations, upgrading nuclear security in other locations around the world, building strong security cultures in which nuclear staff do not cut corners on security, and more. As with the problems in the U.S. Air Force, many of these nuclear security issues are difficult to boil down into simple quantitative metrics of progress or decline.

Policymakers often ask: "how many places with nuclear weapons or materials in the world are insecure, and how long would it take and how much would it cost to fix them all?" Unfortunately, there is no simple answer to these questions. The answer would depend on (a) what threats one judged these stockpiles should be protected against—which may vary from country to country, as the capabilities of terrorists and thieves do; (b) the reliability with which they should be protected against these threats; and (c) the degree to which that level of protection was expected to last into the future. Moreover, the time and cost to achieve any given level of security depends on diplomacy and cooperation with a large number of countries around the world where these stocks reside; American officials can and should set goals for when they will try to achieve certain milestones, but meeting those goals depends on a wide range of factors not controlled from Washington.

Further complicating the answer, the issues with nuclear warhead controls in the U.S. Air Force are a reminder that nuclear security is not like a light switch that can be flicked from "off" to "on" and will then stay on indefinitely. Rather than an off-on switch, nuclear security is a spectrum, on which there is always more that could be done, and more that could be spent, to improve security—if the additional risk reduced was judged to be worth the cost and effort. No matter what security measures are put in place, they will not be proof against a large enough and capable enough conspiracy, or against the collapse or takeover of the state where the nuclear stockpile exists. Moreover, sustaining nuclear security for the long haul is always an issue; in the absence of major incidents, attention focused on nuclear security

[7] For recommendations on steps the United States should take to get its own nuclear security house in order and better position itself for international leadership, see Matthew Bunn, "The Risk of Nuclear Terrorism—And Next Steps to Reduce the Danger," Testimony to the Committee on Homeland Security and Governmental Affairs, U.S. Senate, 2 April 2008; and 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 8 July 2008).

tends to wane over time, and new weaknesses arise.

Thus, helping countries install improved nuclear security systems is a critical tool for reducing the risk of nuclear theft and terrorism, but it can never reduce the risk at any given site to zero. Indeed, while the United States or other donors can help install equipment and provide training, many of the key elements of effective nuclear security systems are things nations must inevitably do for themselves. External parties may have only limited influence over such tasks as providing appropriate numbers of well-trained, well-equipped, well-paid, and well-motivated guards; enacting and enforcing appropriate nuclear security rules; and ultimately committing to reduction, consolidation, or elimination of the stockpiles themselves. For these reasons, the word "secured," so often used in U.S. government press releases, should be banished from the nuclear policy vocabulary as a description of what particular security upgrade programs have accomplished; it conveys a sense—however unintended—that there is no longer any need to worry about the sites so described, and that this will be true indefinitely.[8]

Ideally, one would like to measure the actual risk of nuclear theft and terrorism; whether that risk is increasing or decreasing; and by how much. Unfortunately, no method exists to assess these risks directly. Hence, all the measures of progress the U.S. government uses to track these efforts, and all the measures I discuss in this report, can only be approximate indicators of progress in addressing one part of this multi-faceted problem. Indeed, too great a focus on particular metrics can lead to "goal displacement," in which managers focus on doing a lot of whatever activity is captured by the metric, without thinking more broadly about whether other approaches might do more to reduce the risk they are supposed to be addressing.[9] As the saying goes, "you get what you measure."

Moreover, the numerical measures reported by the government, and those used in this report, leave out many essential elements of the nuclear security picture. A building may have excellent barriers and detectors installed, but are the guards at that building easily corrupted to look the other way? Do the staff turn those intrusion detectors off at night? What is the chance that insiders who know how to defeat the systems will conspire to steal material without detection? What is the chance of an attack by outsiders that is larger and more capable than the security system can cope with? Will site managers and their superiors provide the money and attention needed to operate and maintain these upgraded systems indefinitely? The answers to these questions are crucial to whether the security in place at those buildings is enough to cope with the threat—but those answers do not show up in easily quantifiable metrics. As Albert Einstein is reported to have remarked: "Not everything that counts can

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[8] The National Nuclear Security Administration (NNSA) has recently stopped using buildings "secured" for its formal presentations of its progress metrics, substituting the less misleading measure of buildings where upgrades have been "completed". See U.S. Department of Energy, *FY 2009 Congressional Budget Request: National Nuclear Security Administration*, vol. 1, DOE/CF-024 (Washington, D.C.: DOE, 2008; available at http://www.cfo.doe.gov/budget/09budget/Content/Volumes/Volume1a.pdf as of 9 June 2008), p. 497. To date, however, NNSA press releases and speeches still refer to the buildings they have "secured."

[9] For a useful recent consideration of the problem of measuring progress in reducing risks, see Malcolm K. Sparrow, *The Character of Harms: Operational Challenges in Control* (Cambridge, U.K.: Cambridge University Press, 2008), especially Chapter 6.

be counted, and not everything that can be counted, counts."[10]

To try to paint a more complete picture of progress made and steps yet to be taken, this chapter focuses on a qualitative assessment of the state of progress in several key areas of action for preventing nuclear terrorism. The principal focus here is on securing nuclear stockpiles at their source, as that offers the biggest "bang for the buck" in reducing the risk of nuclear terrorism. Terrorists cannot make a nuclear bomb without the necessary nuclear material, so if the stockpiles of nuclear warheads, plutonium, and highly enriched uranium (HEU) can be reliably protected, nuclear terrorism can be prevented. But once a nuclear warhead or nuclear material is stolen from the site where it is supposed to be, it could be anywhere, and finding it or the terrorists who are planning to use it is an extraordinary challenge. In addition to the chapter's principal focus, I also offer brief assessments of progress and challenges in other elements of the effort to prevent nuclear terrorism.

The first section below discusses what has and has not been done to help different countries around the world to improve their security measures for nuclear stockpiles. The second section discusses what has and has not been done to consolidate these stockpiles to fewer locations, achieving greater security at lower cost. Such consolidation is a critical nuclear security objective, for the only way to ensure that nuclear material will never be stolen from a particular building is to ensure that there is no nuclear material there to steal—and some facilities where plutonium or HEU exist today, such as research reactors on university campuses, are never likely to have the kind of security appropriate for handling the essential ingredients of nuclear bombs in a world of sophisticated terrorists.[11] These programs are principally sponsored by the National Nuclear Security Administration (NNSA) at the U.S. Department of Energy (DOE) and the Cooperative Threat Reduction (CTR) program implemented by the Defense Threat Reduction Agency (DTRA) at DOD. (Such threat reduction programs, and particularly the CTR program at DOD, are often known as Nunn-Lugar, after Senators Sam Nunn and Richard Lugar, who sponsored the 1991 legislation that established the DOD program.)

The third section below goes beyond a country-by-country approach to assess what is being done to put in place appropriate policy frameworks for nuclear security—such as effective means of organizing the overall effort, or global nuclear security standards. Beyond that, briefer sections assess progress in disrupting terrorist nuclear plots; interdicting nuclear smuggling; preventing and deterring conscious state decisions to transfer nuclear weapons or materials to terrorists; impeding terrorist recruitment of nuclear expertise; reducing nuclear stockpiles and ending further production; and international monitoring of nuclear stockpiles.

After this qualitative assessment, the next chapter explores a series of quantitative indicators, focusing on programs to secure and consolidate nuclear stockpiles.

[10] For further discussion of the difficulties of measuring progress in improving nuclear security, and of what threats improved nuclear security measures can and cannot address, see Matthew Bunn, *Securing the Bomb 2007* (Cambridge, Mass.: Project on Managing the Atom, Harvard University, and Nuclear Threat Initiative, 2007; available at http://www.nti.org/securingthebomb as of 28 March 2008), pp. 45-64.

[11] For a useful discussion of the importance of removing stocks entirely from key locations, as opposed to attempting to upgrade security enough at all the existing locations of these stocks, see William C. Potter, "Nuclear Terrorism and the Global Politics of Civilian HEU Elimination," *Nonproliferation Review* 15, no. 2 (July 2008).

These chapters focus primarily on the programs to improve controls over nuclear weapons, materials, and expertise that have been 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.[12] 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. 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. A broad agenda of action is still necessary to ensure that all stockpiles of nuclear weapons and the materials needed to make them worldwide are effectively secured from theft.

Strengthening Nuclear Security: Steps Taken and Work Yet to Do

Programs to improve nuclear security should have a simple goal: to ensure that all nuclear weapons, HEU, and separated plutonium worldwide are sustainably protected against the kinds of threats that terrorists and criminals have shown they can pose. Facing terrorists with global reach, nuclear security is only as strong as its weakest link: insecure nuclear stockpiles anywhere are a threat to everyone, everywhere.

Security for civilian stocks and military stocks

In most cases, security for nuclear weapons and materials in the military sector (such as nuclear weapons and HEU naval fuel) is stronger than security in the civilian nuclear sector, where the materials are not on military bases and managers and staff are more focused on commercial and scientific objectives, and less on security objectives. There are exceptions, however: the Air Force incidents described at the outset, and a variety of past and present issues in countries such as Russia and Pakistan, make it clear that the security of military stockpiles cannot be taken for granted. Similarly, there are some civilian sites—such as the large plutonium stores at Sellafield in the United Kingdom and at La Hague in France—that appear to be reasonably well secured. As might be expected, sites with very little revenue—such as HEU-fueled research reactors that are underutilized—tend to have particular security weaknesses. Nuclear security rules, and the degree to which they are effectively enforced, also vary from one country to the next, and between different sectors within individual countries. In the United States, for example, DOE's post-9/11 nuclear security rules are substantially more stringent than the rules that facilities regulated by the Nuclear Regulatory Commission (NRC) must meet—even when these facilities have essentially identical types of nuclear material.[13] Ultimately, the goal should be to

[12] 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.

[13] This distinction is based on government versus private ownership, not on military versus civilian

reduce the number of sites where nuclear weapons or significant stocks of HEU or separated plutonium exist to the minimum possible, and to ensure that all of the remaining sites, whether civilian or military, are brought up to the security level of the best military sites today.[14] Indeed, because getting the needed nuclear material is by far the most difficult part of making a nuclear bomb, significant stocks of plutonium and HEU should be secured and accounted for to the same security standards used for nuclear weapons themselves—an approach known as the "stored weapon standard."[15]

roles. Some of DOE's HEU facilities are entirely civilian, while the two large HEU processing facilities regulated by the NRC, BWXT and Nuclear Fuel Services, do much of their work fabricating fuel for the U.S. nuclear navy. For a discussion of the substantial difference in security levels at DOE and NRC-regulated facilities, and a recommendation for similar levels of security for similar types of material regardless of ownership, see U.S. Congress, Government Accountability Office, *Nuclear Security: DOE and NRC Have Different Security Requirements for Protecting Weapons-Grade Material from Terrorist Attacks*, GAO-07-1197R (Washington, D.C.: GAO, 2007; available at http://www.gao.gov/new.items/d071197r.pdf as of 7 July 2008).

[14] By a "significant" stock, I do not mean a "significant quantity" as defined by the IAEA, but rather anywhere where there is enough separated plutonium or HEU to represent a substantial fraction of the amount needed for a bomb—for example two kilograms of plutonium or 5 kilograms of U-235 contained in HEU, which IAEA recommendations define as a "Category I" quantity, requiring the highest levels of security.

[15] See 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 18 June 2008). Of course, this refers to those stored nuclear weapons that meet the highest security standards, not to stored nuclear weapons whose security measures are weak and require major upgrades. Stored nuclear weapons would typically have security systems designed to defend against substantial outsider attacks, theft by an insider, or an outside attack with inside help. The specific types of threats they must protect against are typically specified in a well-enforced rule specifying a "design basis threat." Such systems typically include multiple layers of fencing and barriers with multiple types of intrusion detectors; well-trained, well-equipped, and well-motivated armed guard forces, sufficient to defeat the specified threats; two-person or three-person rule to ensure that no one is ever alone with the nuclear weapons; regular, detailed accounting of the weapons to ensure that nothing is missing; elaborate, carefully monitored procedures for any movement of or access to the nuclear weapons; regular training and exercises to test the system's capability and identify weaknesses to be addressed; mechanisms for independent inspection, testing, and review; and in-depth personnel reliability programs designed in the hope of ensuring that only trustworthy people are granted access to the nuclear weapons or information about their security. Such systems are typically designed to provide "defense in depth," so that the failure of any one barrier or detector does not lead the whole system to fail.

Plan of this section

This section assesses progress made in strengthening nuclear security in: Russia (where most cooperative threat reduction programs have focused since the collapse of the Soviet Union); Pakistan, India, China, and North Korea (the developing countries with nuclear weapons, some of which also have large civilian nuclear programs); developing and transition countries with small nuclear programs (all of which are non-nuclear-weapon states participating in the NPT); developed countries; and in the United States itself. Table 2.1 summarizes this assessment. Because of the long-standing in-depth cooperation between the United States and Russia on nuclear security—still ongoing despite the post-Georgia downturn in U.S.-Russian relations—more has been done there and more information is available about nuclear security in Russia, so the discussion of Russia below is the most in-depth. But as the assessment in this chapter makes clear, the danger of nuclear theft is a global problem, requiring a global solution, not just a problem in the states that were once part of the Soviet Union.

Russia

In Russia, security for nuclear weapons, plutonium, and HEU has improved dramatically since the 1990s, though serious issues remain. As discussed in more detail later in this chapter, most nuclear warhead sites and buildings have had upgraded security and accounting systems put in place with U.S. assistance. Even at sites where U.S.-sponsored upgrades have not occurred or are not completed, the most egregious weaknesses of the past—gaping holes in security fences, lack of any detector at all to set off an alarm if someone were carrying out bomb material in a briefcase—appear to have been fixed. It is unlikely that there is any facility with nuclear weapons, plutonium, or HEU in Russia today where the theft approaches that succeeded in the 1990s—in some cases, one insider with no particular plan simply taking material and leaving the facility without detection—would succeed today. At the same time, the improving Russian economy, increased revenues from nuclear electricity and nuclear exports, and huge Russian government investments in the nuclear industry have largely eliminated the 1990s-era desperation that created additional incentives and opportunities for nuclear theft, with workers in those years going unpaid for months at a time, guards leaving their posts to forage for food, and electricity for detector and alarm systems sometimes shutting off over unpaid electricity bills. For better or for worse, strengthened central control and the heavy presence of the security services at many nuclear sites also contribute to deterring attempts at nuclear theft. Overall, the risk of nuclear theft in Russia has been reduced to a fraction of what it was a decade ago.[16]

Nevertheless, nuclear theft in Russia remains a real possibility. Several key factors create strong grounds for concern that insiders or outsiders (or both working together) might be able to overcome the nuclear security measures in place. These include widespread insider corruption and theft; sophisticated, large-scale terrorist attacks; poorly trained and motivated conscript guard forces; continuing underinvestment in nuclear security, which particularly calls into question whether current security measures will be sustained; ongoing weaknesses in nuclear security rules; and weaknesses in security culture. There are, however, important signs of progress in each of these areas—with the important exception of corruption and insider theft, which appear to be growing.[17]

Insider corruption and theft. Russia is afflicted with massive, systemic corruption and insider theft. Russian President Dmitry Medvedev has identified corruption as one of the top threats to Russia's national security and has announced an anti-corruption campaign.[18] One senior

[16] For more in-depth information and references, see Matthew Bunn, "The Threat in Russia and the Newly Independent States," 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/threat/russia.asp as of 2 January 2007).

[17] A survey in 2005, for example, found that the estimated total amount of all bribes paid in Russia had increased dramatically since 2001. See Steven Lee Meyers, "Pervasive Corruption in Russia is Called 'Just Business'," *New York Times,* 13 August 2005 available at http://www.nytimes.com/2005/08/13/international/europe/13russia.html as of 11 November 2008. (For a thoughtful critique of the study, pointing out that the large increase in value per bribe suggests that the risk of taking a bribe is actually increasing as anti-corruption measures take effect, making it require a higher price for bribe-taking to be worthwhile, see Peter Lavelle, "How Corrupt is Russia?" *United Press International,* 2 November 2005, available at http://www.spacedaily.com/reports/Analysis_How_Corrupt_Is_Russia.html as of 11 November 2008.)

[18] "Reuters interview with Medvedev", Reuters, 25 June 2008 available at http://uk.reuters.com/article/

Russian prosecutor has estimated that "the revenues of our bureaucrats from corrupt activity" amount to some $120 billion per year, one-third of Russia's federal budget.[19] Of the states that have either nuclear weapons or significant amounts of high-quality weapons-usable materials, only Belarus fares worse than Russia in Transparency International's rankings of perceived levels of corruption.[20] This corruption has penetrated into the military, the security services, and the nuclear establishment as well. Former Minister of Atomic Energy Evgeniy Adamov's conviction for stealing millions of dollars from the HEU Purchase Agreement is only the tip of the iceberg. In 2003, the chief of security for one of Russia's largest HEU and plutonium facilities warned that guards there were often corrupt, becoming "the most dangerous internal adversaries."[21] Similarly, 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—including easy passage into the closed city after payment of a small bribe to the guards.[22] The firing of Major General Sergey Shlyapuzhnikov, who was responsible for helping to ensure appropriate guarding of the closed nuclear cities but instead helped to organize smuggling in and out of closed territories, was described in Chapter 1, and is emblematic of the problem.[23] In May 2008, a Ministry of Interior (MVD) colonel was reportedly arrested for soliciting thousands of dollars in bribes to overlook violations of security rules in the closed nuclear city of Snezhinsk.[24]

Not only can corruption open gaping holes in security systems—as in the tragic case in which a bribe to airport security officials allowed a suicide bomber onto a Russian aircraft[25]—but the culture of

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topNews/idUKL2555064220080625 as of 12 November 2008; Janet McBride and Michael Stott, "Poverty and Corruption Threaten Russia: Medvedev," Reuters, 25 June 2008 available at http://www.reuters.com/article/topNews/idUSL248493820080625 as of 12 November 2008.

[19] "Russian Officials Said to Steal $120 bln a Year," *Reuters*, 6 June 2008.

[20] In the ratings for 2007, Russia received a rating of 2.3 out of 10 (where higher ratings are better), putting it at 143 out of 180 countries ranked (with 180 being most corrupt)—a slide of more than 20 places in the ranking from the previous year. Belarus, with a rating of 2.1, ranked 150. The only other states with substantial amounts of nuclear material that were close were Pakistan (2.4, 138th), Libya (2.5, 131st), and Ukraine (2.7, 118th). See Transparency International, *Corruption Perceptions Index 2007* (Berlin: TI, 2007; available at http://www.transparency.org/policy_research/surveys_indices/cpi as of 25 June 2008).

[21] U.S. House of Representatives, *FY 2006 Energy and Water Appropriations Act*, 109th Congress, 1st Session, H.R.2419 (2005; available at http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=109_cong_public_laws&docid=f:publ103.109 as of 8 July 2008).

[22] 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.

[23] "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*, www.rg.ru, 2 June 2006 [translated by Anatoly Dianov].

[24] "An Employee of the Department of Classified Facilities of the MVD Was Arrested in Snezhinsk: What Incriminates the 'Silovic'," www.ura.ru, 29 May 2008 [translated by Jane Vayman].

[25] Two female terrorists carried bombs onto two planes in August 2004, destroying both. They appeared at the airport without tickets, but bribed a ticket scalper to sell them tickets without proper identification; the scalper then helped one of them bribe a ticket-checker to get on the plane. See, for example, Peter Baker and Susan B. Glasser, "Russian Plane Bombers Exploited Corrupt System," *Washington Post*, 18 September 2004, available at http://www.washingtonpost.com/wp-dyn/articles/A30042-2004Sep17.html as of 11 November 2008. For a discussion of this case and other links between corruption and terrorism, see Simon

corruption and insider theft go hand-in-hand. Insider theft is endemic in Russia —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.[26] Nuclear facilities are not immune from such insider theft. 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."[27] In 2006, Colonel Yury Navrotsky was accused of stealing 14 tank cars of fuel from nuclear warhead facilities in Russia's Far East.[28] 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.[29]

While Russian President Dmitry Medvedev is launching a new anti-corruption campaign, there does not yet appear to be any targeted anti-corruption program for the nuclear industry or for the MVD troops that provide most of its guards, and the U.S. government has not made any visible effort to convince Russia to start one. NNSA and DOD have provided assistance to strengthen "personnel reliability" programs, but this has consisted primarily of drug and alcohol testing equipment and notoriously unreliable lie detectors; whether these efforts have significantly reduced insider threats is unclear. Security upgrades such as moving nuclear material to vaults to which all access is monitored, and portal monitors to set off an alarm if anyone tries to carry out a substantial amount of plutonium or HEU will certainly help reduce insider threats—but an internal NNSA review concluded that insider threats remained a major problem.[30]

Large-scale terrorist attacks. Nuclear facilities in Russia also face a serious threat

Saradzhyan and Nabi Abdullaev, "Disrupting Escalation of Terror in Russia to Prevent Catastrophic Attacks," *Connections* (Spring 2005), pp. 111-129.

[26] 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.

[27] 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).

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

[29] 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.

[30] Interview with NNSA official, October 2007.

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 police squads, overwhelmed local forces, who did not receive reinforcements from federal security service troops for several hours.[31] (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.) Major-General Igor Valynkin, while serving as the commander of the force that guards Russia's nuclear warheads, confirmed that two incidents of terrorist teams carrying out reconnaissance at nuclear warhead sites had occurred in 2001; the Russian state newspaper reported two more such incidents focused on nuclear warhead transport trains.[32] 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."[33] Similarly, in mid-2007, Nikolai Patrushev, head of the Federal Security Service (Russian acronym FSB, the successor to the KGB) warned that his agency had received reports that "terrorists are striving to gain access to weapons of mass destruction and technologies for producing them," and hence the National Anti-Terrorist Committee (which Patrushev chairs) would carry out a thorough review of the adequacy of security measures at nuclear and space facilities in closed cities.[34] It appears, however, that the threat of sophisticated, large-scale outsider attack has declined since the Beslan attacks, as Russian counter-terrorism successes—however brutally achieved—appear to have significantly reduced Chechen rebels' ability to organize and mount large attacks.[35]

Poorly trained and motivated conscript guard forces. Nuclear weapon sites in Russia are guarded by a well-trained, professional military force, the 12th Main Directorate of the Ministry of Defense

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

[32] 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. For the train incidents, see Vladimir Bogdanov, "Propusk K Beogolovkam Nashli U Terrorista (a Pass to Warheads Found on a Terrorist)," *Rossiiskaya Gazeta*, 1 November 2002.

[33] "Internal Troops to Make Russian State Facilities Less Vulnerable to Terrorists," RIA-Novosti, 5 October 2005

[34] See, for example, Madina Shavlakova, "Closed Formations: Socially Dangerous," *Gazeta,* 6 June 2007 [translated by Elena Leonova in *What the Papers Say,* 6 June 2007].

[35] See, for example, Brian D. Taylor, "Putin's 'Historic Mission': State-Building and the Power Ministries in the North Caucasus," *Problems of Post-Communism,* Vol. 54, No. 6, November/December 2007, pp. 3-16.

(known as the 12th GUMO, its Russian acronym). At most weapons-usable nuclear material sites, by contrast, the main response forces are from the MVD, some of whom are poorly paid and poorly trained conscripts.[36] The chief of security 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.[37] 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.[38] 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.[39] The MVD has been working to improve conditions for these guards and increase the proportion of them who are professionals. In addition, the state-owned firm "Atomgard", which attempts to recruit security professionals from military and law enforcement agencies, has taken over much of the security responsibility at a few large Rosatom nuclear material sites. NNSA has been providing equipment and training to nuclear guard forces, helping to finance dedicated training facilities for nuclear guards, and has been been discussing assistance with a personnel reliability program to screen new recruits and conscripts.[40]

Continuing underinvestment in nuclear security and sustainability. 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—some of which still have few sources of income—have to come up with the money to fund most nuclear security and accounting measures. 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 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.[41] The head of Rosatom's physical protection firm, Eleron, publicly estimated in May 2005 that funding for physical protection covers

[36] 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.

[37] 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 12 May 2008).

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

[39] "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).

[40] Information provided by NNSA, October 2008.

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

only 30 percent of the need.[42] Three out of four civilian nuclear facilities visited by investigators from the U.S. Government Accountability Office in 2006 (all of which were research facilities with little commercial revenue) expressed concern that they might not be able to afford to maintain the upgraded security systems at their sites when U.S. assistance phased out.[43] A leading Russian expert estimated in 2005 that physical protection at Russian nuclear sites receives only 30 percent of the funding required.[44]

While the Russian government does not publish information on its nuclear security spending (which comes from many different accounts),[45] publicly available information suggests that the situation is improving. The Russian government has dramatically increased its investment in the nuclear sector, most nuclear weapons complex facilities and sites engaged in for-profit activities now have plenty of cash, and some of this is spilling over to investments in nuclear security. (Small sites focused on research, however, remain financially strapped.) In 2007, the 12th GUMO told U.S. officials that it had asked for and received a commitment from the Finance Ministry to provide additional funding to sustain security measures at nuclear weapon sites—but the total was only in the range of $30 million per year.[46] In mid-2007, the Russian government approved a major program for improving nuclear and radiological safety over 2008-2015, with a budget of $5.8 billion. While the program does include mentions of improving physical protection and accounting for nuclear and radiological materials, the principal focus is on nuclear cleanup and safety improvements, and it appears that security measures will receive only a small fraction of the total funding.[47] As part of ongoing sustainability efforts, NNSA and DOD have discussed nuclear security budgets at Russian sites, to identify all the steps that must be taken to get each site prepared for sustaining an effective security and accounting program on its own, and are working with the sites to develop estimates of the annual security and accounting costs they are likely to face. But whether the needed money will be forthcoming, particularly at sites that generate

[42] 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.

[43] U.S. Congress, Government Accountability 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 7 July 2008), p. 27.

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

[45] Typically, individual sites are expected to pay most of the costs of providing security and accounting at their sites. Physical protection measures such as barriers, gates, and intrusion detectors and the budgets for them are controlled by the site security chief (typically a deputy to the site CEO), while nuclear material accounting and control measures are typically paid for from accounts controlled by the site's chief engineer. MVD guard forces and their equipment are paid for from MVD budgets. The FSB is also an important participant in nuclear security, with its activities paid for from its own budget. The 12th GUMO has its own budgets for nuclear warhead security, but so do some of the services that control warheads.

[46] Interview with NNSA official, October 2007.

[47] The full text of the "Federal Targeted Program for Nuclear and Radiation Safety for 2008-2015" has not been publicly released. For an official confirmation of the program's approval and budget, see, for example, "Head of Rosatom Gives Press Conference to Regional Media," *RIA Oreanda,* 5 October 2007. Earlier, the "concept" for the program had been approved in Russian Federation Directive #484-r, 19 April 2007; the concept has only a few brief mentions of security measures.

little commercial revenue, remains to be seen.

More broadly, NNSA and DOD have been working intensely with their Russian counterparts in an attempt to ensure that Russia will sustain effective nuclear security and accounting measures after U.S. assistance phases out; the U.S. Congress has directed that the goal should be a nuclear security system entirely sustained by Russia's own resources by the beginning of 2013.[48] NNSA and Russian officials have agreed on seven overarching elements of a sustainable security and accounting system, and are working together to attempt to ensure that each site has each of those elements in place.[49] 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. (See below for a discussion of measures to convince foreign leaders and nuclear managers that it is worth giving nuclear security higher priority in their own investments.)

Ongoing weaknesses in nuclear security rules. 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.[50] 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 physical protection regulation (though that rule is very general, and depends for its effectiveness on specifics laid down in agency-level rules, many of which have not yet been updated).[51] But Russia's nuclear security rules still have important weaknesses, its regulatory agency has few resources for inspection and enforcement,[52] and the regulators have

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

[49] For a useful overview of NNSA's seven elements of sustainability, with NNSA'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.

[50] 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).

[51]" "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).

[52] 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

far less power than Rosatom, the state corporation they are supposed to regulate. 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.[53] The nuclear regulators have no authority to regulate the MVD forces that provide most of the guards for nuclear sites; instead, the MVD regulates itself. Moreover, 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; and in the spring of 2008, Rostekhnadzor itself was submerged within the Ministry of Natural Resources (one of the key agencies Rostekhnadzor is supposed to regulate). 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.[54] But there is still a long way to go to build a structure of effective rules, effectively enforced—without which, sustainable nuclear security is unlikely to be achieved. Ultimately, it is up to each state with nuclear weapons or weapons-usable nuclear materials to give its regulators the resources, authority, and expert personnel they need to ensure that all such stockpiles are effectively secured and accounted for; U.S. programs can help, but cannot determine the outcome.

Weaknesses in security culture. Building strong security cultures—strengthening the habit, among all security-relevant personnel, of taking security seriously and taking the actions needed to ensure high security—is critical to the success of nuclear security improvement programs. As Gen. Eugene Habiger, former DOE "security czar" and former commander of U.S. strategic forces, put it: "good security is 20 precent equipment and 80 percent culture."[55] In Russia, 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.[56] As noted earlier,

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.

[53] Interviews with NNSA officials, June 2005 and June 2007.

[54] 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 NNSA officials, July 2006 and June 2007.

[55] Interview by author, April 2003.

[56] 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: Secu-*

in 2003 the security chief at Seversk, on of Russia's largest plutonium and HEU processing facilities, 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.[57]

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 the massive Seversk site). Moreover, the change in attitudes that have come naturally with the new security equipment NNSA has helped install should not be understated: when material is stored in a vault with a huge steel door which no one can access alone, arrived at through layers of fences, bars, and detectors, it creates a different sense of the importance of care in controlling that material than if it is tossed in the equivalent of a high-school locker with a padlock that can be snapped in seconds with a bolt-cutter from any hardware store (as often used to be the case).

But whether ongoing efforts to strengthen security culture 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.[58] Efforts to strengthen security culture in a global context are discussed below.

Problems with nuclear material accounting and control (MC&A). Material control measures such as the 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, critical 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

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rity 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 percent20Culture percent20Report percent2020041118.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).

[57] 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).

[58] A classic text on organizational culture (though one much critiqued in some circles as too focused on managers' role in culture) 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).

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"), which 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.[59] Many sites with large numbers of nuclear material containers built up over decades of operation have not invested in actually measuring how much material is in each of those containers—that is, a full, measured inventory of the material on hand (as opposed to what paper records say ought to be in those containers). Here, too, the situation appears to be improving. NNSA has provided Russian nuclear material facilities with equipment for accurate accounting of nuclear material, effective tamper-indicating devices (TIDs), and more. With help from NNSA, Russia is putting in place new accounting rules and new standards for TIDs; regular measured inventories of material on-hand are becoming more common; and a computerized national inventory system is up and running (though the reports to it are not at a level of detail that would make it possible to identify thefts or diversions).

The role of civil society. 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.)[60] The crackdown on non-government organizations in recent years has further undermined the prospects for genuinely independent review and pressure in these highly sensitive areas.

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."[61]

Pakistan

As described in Chapter 1, Pakistan's nuclear stockpiles are hundreds of times smaller than Russia's, are believed to be located at only a small number of sites,

[59] 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, NNSA 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 NNSA, September 2007.

[60] 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 9 July 2007).

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

and are thought to be heavily guarded—though possibly with a "guards, guns, and gates" approach rather than relying on modern security and accounting equipment.[62] But nuclear stockpiles in Pakistan face immense threats, both from nuclear insiders (some of whom have strong jihadi sympathies and a demonstrated willingness to sell nuclear weapons technology) and from outsider attack. Pakistan is now al-Qaeda's world headquarters, and that in itself makes it a frightening location for nuclear weapons and weapons-usable materials. The unrest and political discord in Pakistan since late 2007 does not, however, appear to have undermined the cohesion of the army and the security services, which are the key to the security of Pakistan's nuclear stockpiles, or raised any near-term prospect of a government takeover by Islamic extremists. The extremists' growing strength, and the fractious civilian government's seeming unwillingness or inability to take them on, however, may increase the risk that an extremist attack on a nuclear facility would succeed.

Following the 1998 nuclear tests and the revelation that Pakistan's A.Q. Khan had been leading a global black-market nuclear technology network, Pakistan undertook major reforms of its nuclear command, control, and security systems.[63] Overall management of the nuclear stockpile is now under the Strategic Plans Division, which has a special unit that is reported to have roughly 1,000 troops focused on security for nuclear assets.[64] Pakistani nuclear weapons are reported to be stored separately from their delivery systems, in disassembled form, and with key components of each weapon in separate buildings, so that thieves would have to succeed in two separate thefts to steal a complete bomb.[65] In addition, Pakistani officials have asserted that Pakistani nuclear weapons are equipped with systems to prevent unauthorized personnel from being able to detonate a bomb if they got hold of it, which they have described as "comparable" to U.S. Permissive Action Links (PALs).[66] It is not clear, however, whether Pakistan makes use of systems comparable to modern U.S. PALs, which are integral to the design of the weapon,

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[62] 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). See also Mahmud Ali Durrani, "Pakistan's Strategic Thinking and the Role of Nuclear Weapons" Cooperative Monitoring Center Occasional Paper 37, SAND 2004-3375p (Albuquerque, New Mexico, July 2004; available at http://www.cmc.sandia.gov/cmc-papers/sand2004-3375p.pdf as of 2 July 2008); Shaun Gregory, "*The Security of Nuclear Weapons in Pakistan*, Pakistan Security Research Unit (PSRU) Brief Number 22, (18 November 18 2007, available at http://spaces.brad.ac.uk:8080/download/attachments/748/Brief_22finalised.pdf as of 24 September 2008); and Kenneth N. Luongo and Brig. Gen. (Ret.) Naeem Salik, "Building Confidence in Pakistan's Nuclear Security," *Arms Control Today,* (December 2007, available at http://www.armscontrol.org/act/2007_12/Luongo.asp as of 2 July 2008).

[63] International Institute for Strategic Studies, *Nuclear Black Markets: Pakistan, A.Q. Khan and the Rise of Proliferation Networks: A Net Assessment* (London: IISS, 2007), pp. 112-117.

[64] International Institute for Strategic Studies, *Nuclear Black Markets*, p. 112.

[65] See, for example, David Albright, "Securing Pakistan's Nuclear Infrastructure," in 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 2 July 2008).

[66] See, for example, Hamid Mir, interview with former Pakistan Atomic Energy Commission Chairman Samar Mubarakmand, *Geo-TV,* 5 March 2004, available at http://www.pakdef.info/forum/archive/index.php/t-9214.html as of 2 July 2008. For overviews of publicly available information on PALs, see Donald R. Cotter, "Peacetime Operations: Safety and Security," in *Managing Nuclear Operations*, ed. Ashton B. Carter, Charles A. Zraket, and John D. Steinbruner (Washington, D.C.: Brookings Institution, 1987); Peter Feaver, *Guarding the Guardians: Civilian Control of Nuclear Weapons in the United States* (Ithaca, N.Y.: Cornell University Press, 1992).

extremely difficult to bypass, and have "limited try" features that will permanently disable the weapon if someone inserts the wrong code too many times—or whether they are relying on systems that would be much easier to bypass, such as locks added after the weapons were built.[67]

Pakistan has acknowledged that it is cooperating with the United States to improve nuclear security and accounting measures,[68] but has insisted that this has not involved any access by U.S. personnel to Pakistani nuclear sites.[69] NNSA's International Nuclear Materials Protection and Cooperation program has responsibility for working with Pakistan (and with China and India, the other developing countries with nuclear weapons and with large nuclear infrastructures) to help improve nuclear security—though other agencies of the U.S. government have been involved in nuclear security discussions with Pakistan as well. Neither the United States nor Pakistan has released any information concerning how much progress has been made in this cooperation. Press accounts and a close reading of appropriations documents suggest that NNSA has allocated tens of millions of dollars to this cooperation,[70] suggesting that NNSA has provided substantial quantities of modern security and accounting equipment (such as modern types of intrusion detectors, portal monitors, nuclear material accounting equipment, and the like). In addition, the cooperation has involved extensive discussions and training in assessing the vulnerabilities of nuclear sites against insider and outsider theft, designing upgraded security systems, accurate accounting for nuclear material, use of effective tamper-indicating devices, personnel reliability programs, and more.

While the U.S. and Pakistani governments continue to describe each other as allies, and some Pakistani officials and military officers understand the value of cooperation with the United States in serving Pakistan's own interests, anti-American feeling and suspicion of U.S. government motives—particularly on the nuclear issue—are widespread and deeply felt in Pakistan.[71] A very broad section of the Pakistani military believes that the United States is plotting to seize control of Pakistan's nuclear arsenal and render Pakistan defenseless. This level of suspicion often creates a poisonous atmosphere that can make cooperation in sensitive nuclear areas difficult or impossible.

Insider threats. The insider problem in Pakistan is exemplified by both the A.Q. Khan network—in which Pakistani participants marketed not only centrifuge technology but nuclear bomb designs (including an advanced design light enough to be used on a ballistic missile)—and by the two Pakistani nuclear weapon scien-

[67] See Albright, "Securing Pakistan's Nuclear Infrastructure."

[68] 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 2 July 2008).

[69] In the past, the United States has, on occasion, been similarly willing to supply nuclear security equipment to Russia without access to the sites where the equipment would be installed, if Russia was going to fund and implement the installation itself.

[70] See, for example, David E. Sanger and William J. Broad, "U.S. Secretly Aids Pakistan in Guarding Nuclear Arms," *New York Times*, 18 November 2007, available at http://www.nytimes.com/2007/11/18/washington/18nuke.html as of 2 July 2008.

[71] For Pakistan's nuclear establishment, the fact that the United States has been willing to negotiate a civil nuclear cooperation deal with India leaving India's nuclear weapons program untouched, but has pointedly refused to do so with Pakistan, heightens suspicions and skepticism of the value of cooperating with the United States.

tists, Sultan Bashiruddin Mahmoud and Abdul Majeed who established a charity to support the Taliban and sat down with bin Laden and Zawahiri to discuss nuclear, biological, and chemical weapons.[72] Mahmoud had been a senior figure in Pakistan's nuclear program, playing a key role in the early days of the enrichment effort (including briefly serving as A.Q. Khan's boss), and leading the design and construction of the Khushab plutonium production reactor; Mahmoud had long said that Pakistan's nuclear weapons were the property of the whole "ummah," or Muslim community, and had advocated sharing nuclear weapons technology.[73] Former CIA Director George Tenet reports that the two provided al-Qaeda with a rough sketch of a nuclear bomb design, and that U.S. officials were so concerned about the activities of their charity (whose board of directors also included a range of senior retired military officers) that President Bush directed him to fly to Pakistan and discuss the matter directly with Pakistani President Pervez Musharraf.[74] One Pakistani nuclear expert estimated that some 10 percent of Pakistan's nuclear scientists were sympathetic to violent Islamic extremists. Serving Pakistani military officers have cooperated with al-Qaeda in at least two assassination attempts on former president Musharraf[75]—raising the possibility that military officers guarding nuclear weapons might do the same. In 2005, Pakistan established a much more extensive program for screening and monitoring nuclear personnel, which has reportedly had some success in purging people with extremist views from access to nuclear weapons and technologies. This has almost certainly reduced the insider threat—but it is not clear how great a threat remains.[76]

Corruption is, if anything, even more pervasive in Pakistan than in Russia—including in the military and in the nuclear establishment. A government investigation suggested that A.Q. Khan had personally skimmed millions of dollars from the Pakistani nuclear weapons program.[77] Reports suggest that Khan succeeded in corrupting successive directors of security for the Khan Research Laboratories,[78] enabling those parts of the Khan network exports that did not have government authorization to proceed. No one knows what the chances are that extremists might be able to corrupt key nuclear guards or security officials, or that corrupt officials might overlook critical security weaknesses.

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[72] 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. For a somewhat more detailed version, see David Albright and Holly Higgins, "Pakistani Nuclear Scientists: How Much Nuclear Assistance to Al-Qaeda?" (Washington, D.C.: Institute for Science and International Security, 2002; available at http://www.exportcontrols.org/pakscientists.html#back29 as of 2 July 2008).

[73] Albright and Higgins, "Pakistani Nuclear Scientists: How Much Nuclear Assistance to Al-Qaeda?"

[74] George Tenet, *At the Center of the Storm: My Years at the CIA* (New York: HarperCollins, 2007), pp. 266-268.

[75] "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.

[76] For a description, see, for example, Peter Wonacott, "Inside Pakistan's Drive to Guard Its A-Bombs," *Wall Street Journal*, 29 November 2007, p. 1.

[77] For a published account of this episode, see Douglas Frantz and Catherine Collins, *The Nuclear Jihadist* (New York: Twelve, 2007), pp. 252-256. I have supplemented this published account with personal discussions with Hassan Abbas, the National Accountability Bureau investigator assigned to review this corruption information. Abbas' book on Khan, the Pakistani bomb, and its proliferation is forthcoming.

[78] Hassan Abbas, personal communication, May 2008.

Outsider threats. In Pakistan, unfortunately, attacks on nuclear sites by scores or even hundreds of heavily armed and well-trained fighters are a realistic possibility. Taliban-linked extremists now dominate much of the tribal areas of Pakistan, and are increasingly able to carry out operations elsewhere in the country. In 2007, violent Islamic extremists captured 300 Pakistani soldiers—a substantially larger cohort than is likely to be guarding any particular nuclear weapons depot. Given al-Qaeda's intense interest in nuclear weapons and its efforts to recruit Pakistani nuclear scientists, it is very likely that al-Qaeda and its allies have discussed the possibility of assaults on Pakistani nuclear facilities—including the possibility of easing such an assault by recruiting insider help. Pakistan's nuclear establishment has already been a target of more basic attacks: in September 2007, for example, a suicide bomb operation carried out in the garrison city of Rawalpindi targeted a bus carrying employees of the Pakistan Atomic Energy Commission (PAEC, the organization that controls nuclear weapons development) on their way to work, killing four PAEC officials and three bystanders, and injuring many more.[79]

Sustainability, regulation, and security culture. Since the 1998 tests, the 9/11 attacks, and the A. Q. Khan revelations, Pakistan has adopted strengthened nuclear security procedures and regulations. Virtually no specifics as to what these are have been made publicly available, however. Similarly, as there is virtually no public information concerning the kinds of security upgrades that have been implemented, it is impossible to assess how sustainable these improved security measures will be. Nor is there sufficient data to assess security culture in Pakistan; it is clear that Pakistani officials take nuclear security very seriously, but at the same time there have been frequent statements—from former president Musharraf on down—that it is inconceivable that terrorists could make a nuclear bomb or seize any of Pakistan's weapons, and that some combination of India and the United States are the main threats to Pakistan's nuclear stockpiles.[80] Given the relatively new state of U.S.-Pakistani nuclear security 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.

Threats improved nuclear security systems cannot address. It is important to understand that improved nuclear security systems would address some, but not all, of the scenarios that concern U.S. policy-makers. If the Pakistani state collapsed, or Taliban-linked jihadists seized power, or hundreds of well-armed and well-trained jihadists attacked a nuclear site all at once, or senior generals decided to provide nuclear assistance to jihadis, better nuclear security systems would not solve the problem. However large or small these risks may be, other policy tools will be needed to address them.

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[79] The same day, also in Rawalpindi, the extremists also blew up a bus full of employees of Pakistan's Inter-Services Intelligence (ISI)—ironically, an early sponsor of the Taliban. The extremists may have been trying to send the message that no institution and no city was safe from their strikes. See Amir Mir, "Pak Jehadis Target Their ISI Mentors, Kill 33 in Blasts," *Daily News and Analysis*, 5 September 2007.

[80] For a report of a discussion with Musharraf dismissing the risk of nuclear theft and terrorism, see George Tenet, *At the Center of the Storm: My Years at the CIA* (New York: HarperCollins, 2007), p.266. Pakistani concerns over U.S. intentions have been heightened by repeated U.S. press reports that the United States is planning for contingencies in which it might attempt to seize Pakistan's nuclear stockpiles. For a particularly detailed account, see Seymour Hersh, "Watching the Warheads," *The New Yorker*, 5 November 2001, available at http://www.newyorker.com/archive/2001/11/05/011105fa_FACT?currentPage=all as of 11 November 2008.

India

Like Pakistan, India has a relatively small nuclear stockpile at a limited number of sites, which is believed to be heavily guarded.[81] India has plans for large-scale civilian use of plutonium fuels, and eventually of U-233 fuels, though implementation of these is some distance in the future. In India's case, like China's, the amount of information about actual nuclear security practices which is publicly available is small.[82] Nuclear weapons and weapons-usable nuclear material are believed to be located in a small number of facilities under heavy guard. A special security force, the Central Industrial Security Force (CISF), guards both nuclear installations and other especially dangerous or sensitive industrial facilities. Indian experts report that India does perform systematic vulnerability assessments in designing physical protection systems for nuclear facilities and does use some modern security technologies, including access controls and various types of intrusion detectors.[83] Resources available for physical protection appear to be limited, however, and in some cases physical protection systems are aging and have some important weaknesses.[84] India probably faces significantly lower insider threats to its nuclear facilities than Pakistan; it seems much less likely (though not impossible) that people with sympathies to al-Qaeda or other terrorist groups, willing to help with a nuclear theft, would be found among nuclear insiders in India, and, while corruption is widespread in India, it is much less pervasive than it is in Pakistan or Russia.[85] Nevertheless, past incidents such as the assassination of a Prime Minister by her own guards suggest that potential insider threats should be taken seriously.[86] India also faces significantly lower terrorist threats than Pakistan, though it has experienced repeated terrorist attacks, including on defended facilities such as military bases (and the Indian Parliament), suggesting that protection must also be provided against potentially substantial outsider attacks.

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. Remarkably, the United States did not seek to include agreement to cooperate to ensure effective nuclear security as part of its agreement to change nonproliferation rules for the U.S.-India nuclear deal. Since that deal does not require either particular physical protection measures or international

[81] For a summary of publicly available information, see Busch, *No End in Sight: The Continuing Menace of Nuclear Proliferation*. Some additional detail was provided at International Atomic Energy Agency, "IAEA Regional Training Course on Security for Nuclear Installations," Mumbai, India, 11-20 May 2003.

[82] For a summary of other publicly available information, see Busch, *No End in Sight: The Continuing Menace of Nuclear Proliferation*.

[83] See presentations to International Atomic Energy Agency, "IAEA Regional Training Course on Security for Nuclear Installations."

[84] Interview with a U.S. expert who toured the physical protection system at an Indian power reactor, at Indian invitation, in 2003. Personal communication, July 2003.

[85] In Transparency International's index, India and China both rank 72nd, with a score of 3.5 (with 10 being least corrupt), compared to Pakistan, ranked 138th with a rating of 2.4. See Transparency International, *Corruption Perceptions Index 2007*, at http://www.transparency.org/policy_research/surveys_indices/cpi/2007 as of 11 November 2008.

[86] Indira Gandhi was murdered by Sikh members of her personal bodyguard, after her decision to use force to seize the Golden Temple, one of the holiest Sikh shrines, from Sikh extremists. While this issue is not likely to be relevant to potential nuclear terrorists today, the fact that the killing was carried out by carefully screened and highly trusted guards highlights the difficulty of coping with insider threats.

safeguards for India's nuclear weapons, plutonium, HEU, reprocessing plants, or enrichment plants, it is unlikely to offer more than marginal benefits for improving nuclear security and accounting in India. Now that the deal has been approved, the possibility for moving forward on such cooperation may increase, but the politics surrounding it within India have made cooperation with the United States on sensitive matters related to nuclear weapons politically very difficult.

China

China's nuclear stockpiles are somewhat larger than India and Pakistan's. China is thought to have some 200 nuclear weapons, as well as nuclear material processing facilities and a small number of HEU-fueled research reactors. China also has a pilot-scale civilian plutonium reprocessing plant that is expected to begin operation soon.

While public information about China's approaches to nuclear security and accounting is sparse, China's nuclear security system is believed to be heavily dependent on "guards, guns, and gates," as the Soviet system was, with relatively little application of modern safeguards technologies.[87] China does not have a specific "design basis threat" that nuclear facilities must be able to protect against defined in regulations, and systematic engineering approaches to assessing and correcting vulnerabilities are typically not applied.[88] Chinese experts have expressed concern that improved protections against insider theft may now be needed, given China's shift toward a more market-oriented (and more corrupt) society.[89] Outside terrorist attack may someday also be an issue, though not to the same degree as it is in Pakistan or Russia. China does have a continuing problem with terrorist groups, including groups based in China's Islamic minority, which the Chinese government alleges are linked to al-Qaeda.

The United States and China initiated a lab-to-lab cooperation program on technologies for securing and accounting for nuclear materials in the late 1990s, which ultimately included the installation of a demonstration facility for modern safeguards and security technology at the China Institute of Atomic Energy in Beijing, which U.S. participants hoped would create a new standard for securing and accounting for nuclear materials

[87] For a summary of MPC&A in China, see Hui Zhang, "Evaluating China's MPC&A System," in *Proceedings of the 44th Annual Meeting of the Institute for Nuclear Materials Management, Phoenix, Ariz., 13-17 July 2003* (Northbrook, Ill.: INMM, 2003; available at http://belfercenter.ksg.harvard.edu/publication/3201/ as of 4 August 2008). See also the summaries of the sparse publicly available literature in Nathan Busch, "China's Fissile Material Protection, Control, and Accounting: The Case for Renewed Collaboration," *Nonproliferation Review* 9, no. 3 (Fall-Winter 2002; available at http://cns.miis.edu/pubs/npr/vol09/93/93busch.pdf as of 18 June 2008); Busch, *No End in Sight: The Continuing Menace of Nuclear Proliferation*.

[88] Tang Dan, "Physical Protection System and Vulnerability Analysis Program in China: Presentation to the Managing the Atom Seminar" (23 March 2004). In an interview in October 2006, a Chinese physical protection regulator confirmed that at most sites, a systematic vulnerability assessment has not yet been performed.

[89] See Tang Dan et al., "Physical Protection System and Vulnerability Analysis Program in China," in *EU-High Level Scientific International Conference on Physical Protection* (Salzburg, Austria: Austrian Military Periodical, 2002; available at http://www.numat.at/list percent20of percent20papers/tangdan percent20- percent20unkorrigiert.pdf as of 5 April 2006). It is notable that the authors begin with a review of recent changes in Chinese society, with the conclusion that these changes increase the criminal threat and decrease the ability to rely solely on the loyalty of insider personnel.

in China.[90] This cooperation was cut off after the scandal over allegations of Chinese nuclear espionage in the United States. Cooperation with respect to civilian nuclear material resumed in the mid-2000s, and extensive upgrades of protection, accounting, and control technologies were completed at one site in the fall of 2005, as a demonstration 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 design basis threat (DBT), and that detailed vulnerability assessments had not been performed at the vast majority of Chinese sites.[91] So far, China and the United States have not managed to restart cooperation related to security for China's nuclear weapons and military nuclear materials (which represent most of China's stockpiles requiring high levels of nuclear security), but experts from weapons-complex institutions such as the China Academy of Engineering Physics (CAEP) regularly take part in the nuclear security discussions.[92] 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.[93]

[90] See Nancy Prindle, "The U.S.-China Lab-to-Lab Technical Exchange Program," *Nonproliferation Review* 5, no. 3 (Summer 1998; available at http://cns.miis.edu/pubs/npr/vol05/53/prindl53.pdf as of 18 June 2008).

[91] Interviews with Chinese experts, October 2006.

[92] Interview with NNSA official, August 2007.

North Korea

North Korea has only a very small stockpile of nuclear weapons and plutonium, now capped by the freeze and disablement of its plutonium production facilities. (North Korea recently declared that it had a stock of just over 30 kilograms of separated plutonium—a figure many analysts finding surprisingly low, and which will have to be confirmed through analysis of facilities, wastes, and operating records.[94]) Little is known about nuclear security in North Korea, though in such a garrison state, the possibility of an armed group of terrorists attacking and seizing any of this material seems vanishingly small. The more realistic threat would be the possibility that some of the key military officers associated with the program might decide to sell off some of the plutonium. But given the central importance of this material to the North Korean regime, it is very likely that stringent controls have been put in place. Moreover, the small size of the

[93] Data provided by NNSA, September 2007.

[94] Early press reports of North Korea's declaration included a 37-kilogram figure. See, for example, Glenn Kessler, "Message to U.S. Preceded Nuclear Declaration by North Korea," *Washington Post*, 2 July 2008, p. A07. More recent reports have clarified that the amount of plutonium actually separated from spent fuel, and still available after the nuclear test, was declared to be 30.8 kilograms. See, for example, "North Korea Declares 31 Kilograms of Plutonium," *Global Security Newswire*, 24 October 2008 available at http://gsn.nti.org/gsn/ts_20081024_4542.php as of 11 November 2008. In September, 2008, North Korea announced that it was beginning to reverse disablement steps and restart its nuclear program in a dispute over the United States' refusal to remove it from the State Department list of state sponsors of terrorism. The following month, however, the United States moved to take North Korea off the terrorism list and the North returned to disabling its facilities.

stockpile would probably make it difficult to remove any significant amount of this material without detection. A collapse of the North Korean state, however, could destroy whatever controls are in place and create a serious problem of "loose nukes."[95] (Conscious state decisions to transfer nuclear material are a different matter that needs to be addressed by other policies, discussed below.) The United States has not attempted to engage with North Korea on improved nuclear security measures, focusing instead on negotiations aimed at capping and ultimately eliminating this stockpile.

Developing and transition non-nuclear-weapon states

All the other developing and former communist transition countries where weapons-usable nuclear materials exist are non-nuclear-weapon states with small nuclear infrastructures, with from one to a few locations where these materials are present. Nearly all of the other sites with weapons-usable nuclear materials in developing and transition countries are HEU-fueled research reactors. NNSA's Global Threat Reduction Initiative (GTRI) program has been providing assistance to upgrade security at these sites.[96] As discussed in detail below, NNSA-funded security upgrades have been completed at all but a few of the HEU sites in developing and transition countries that were judged to need them. The upgrades NNSA has completed, however, were designed only to ensure that these sites had security measures in place that met rather vague IAEA physical protection recommendations. In many cases, the upgrades would not be sufficient to protect these sites from the kinds of insider and outsider capabilities that terrorists and thieves have demonstrated they can pull together in those countries (an issue discussed in more detail below). Indeed, many of these facilities are in locations such as university campuses, where the kinds of security appropriate for potential nuclear bomb materials would be extremely difficult to put in place and maintain. The Pelindaba site in South Africa where the November 2007 intrusion discussed in Chapter 1 occurred has significantly more extensive security measures in place than most HEU-fueled research reactors do; few other such sites would have a 10,000-volt security fence that intruders would have to get through to penetrate the site, as the intruders successfully did at Pelindaba. As described below, a revision of the IAEA physical protection recommendations, which may include more specific and stringent standards, is now being discussed. If such a revision is approved, GTRI plans to carry out further upgrades for research reactor sites to meet the revised recommendations.[97]

Beyond the question of whether the upgrades being installed at these sites are sufficient to meet the threat, there are the questions of sustainability, security culture, and adequacy of guard forces. Many

[95] Ashton B. Carter, William J. Perry, and John M. Shalikashvili, "A Scary Thought: Loose Nukes in North Korea," *Wall Street Journal*, 6 February 2003, available at http://belfercenter.ksg.harvard.edu/publication/1243/scary_thought.html as of 11 November 2008.

[96] As of this writing (fall-2008),the International Nuclear Materials Protection and Cooperation program, not GTRI, has responsibility for security upgrades at those sites that are in the non-Russian sites in the former Soviet Union. Another part of NNSA has responsibility for the legally required reviews of security at sites with U.S.-origin nuclear material. And yet another office within DOE (the Office of Intelligence and Counterintelligence, outside of NNSA) is responsible for collecting and analyzing information on security at these sites, as part of the Nuclear Materials Information Program (NMIP).

[97] Data provided by NNSA, June 2008.

of these sites have very limited revenue, and NNSA is typically not paying for them to maintain their upgraded security systems beyond an initial warranty period. NNSA is, however, providing funding to help the IAEA provide training and other services that should help with sustainability.[98] With respect to security culture, the reality is that at most of these sites, managers and staff simply do not take seriously the possibility that someone would try to steal HEU from their site—they do not believe that terrorists could make a nuclear bomb if they got such material, they have typically been operating for decades without incident, and they see no reason why that would be likely to change in the future. Such beliefs make it very difficult to convince personnel to follow stringent (and often inconvenient) security procedures over time. And many of these sites are protected by very minimal guard forces.

Among these developing and transition countries, the three sites that have the largest stocks of unirradiated weapons-usable HEU are at Pelindaba, South Africa; Sosny, Belarus; and Kharkiv, Ukraine. Each of these sites has enough fresh, unirradiated HEU for the simplest "gun-type" nuclear bomb, the easiest type for terrorists to construct. South Africa has so far refused U.S. offers to cooperate on upgrading security (even in the aftermath of the November 2007 intrusion), and the most recent annual report of the ministry that controls the site reported "0 percent" progress on putting in place new security regulations, as the relevant agencies have not yet agreed on a DBT that the site should be required to defend against.[99] At Sosny, modest upgrades were completed in the mid-1990s, but further work—including work on sustainability—was delayed by political disagreements with the regime in Belarus. Work on further security upgrades at Sosny has resumed, but is not yet complete.[100] At Kharkiv, upgrades were completed in the 1990s, and further upgrades were implemented more recently, though sustainability and security culture remain important issues. (As discussed below, GTRI is seeking to remove the material from all three of these sites, but there are considerable obstacles to doing so.)

Developed countries

Most of the sites with weapons-usable nuclear material outside the United States and Russia are in developed countries. Some of these sites have substantial stockpiles, ranging from tens of tons of separated civilian plutonium at well-guarded facilities in Britain and France to hundreds of kilograms of HEU at some less well-protected facilities in several countries.

The United States does not finance nuclear security improvements in wealthy states, whether they are states with nuclear weapons such as France, the United Kingdom, or Israel,[101] or non-nuclear-weapon states such as Germany, Japan, and Canada. The United States often seeks, however, through discussions, to convince such states to take steps to strengthen nuclear security, and under U.S. law, the United States conducts occasional visits to confirm that U.S.-origin nuclear material in these countries is protected in accordance with IAEA recommendations. Extensive U.S.-Japanese discussions,

[98] Data provided by NNSA, June 2008.

[99] See Department of Minerals and Energy, *Annual Report 2006/2007* (Johannesburg: DME, 2007), p. 69.

[100] Data provided by NNSA, June 2008.

[101] Given Israel's small stockpile and extensive experience with terrorism, it probably has reasonably stringent nuclear security measures in place, though essentially no information about these measures is publicly available.

for example, helped encourage Japan to strengthen its physical protection rules, though the security measures required in Japan are still modest.[102] Occasional dialogues with several countries on nuclear security are ongoing. Several wealthy countries have significantly strengthened their nuclear security regulations and procedures since the 9/11 attacks.

Nevertheless, the general assumption that all nuclear material in wealthy countries is effectively secured is not correct. Many HEU-fueled research reactors in wealthy countries have minimal security measures in place (particularly in the United States, as discussed below). 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. Similarly, U.S. visitors to a major HEU processing facility in France in 2006 found a wide range of security weaknesses.[103] Transports of separated plutonium and HEU raise particular security vulnerabilities, and occur frequently in some countries—in France in particular.[104]

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 stockpiles than any other country. Annual safeguards and security spending at DOE alone is now in the range of $1.5 billion per year;[105] the private sector and the Department of Defense spend hundreds of millions more each year. Almost all facilities with nuclear weapons or weapons-usable nuclear material are required to be able to defeat a specified DBT;[106] 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, and routinely contribute to revealing important deficiencies that require correction.[107]

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[102] 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.

[103] Interviews with participants in a visit to the CERCA HEU fuel fabrication facility.

[104] For a description of the frequency of civilian plutonium transports, see 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). 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 www.greenpeace.fr/stop-plutonium/en/TimmReportV5.pdf as of 18 June 2008).

[105] U.S. Department of Energy, *FY 2009 Congressional Budget Request: Other Defense Activities*, vol. 2, DOE/CF-025 (Washington, D.C.: DOE, 2008; available at http://www.cfo.doe.gov/budget/09budget/Content/Volumes/Volume2.pdf as of 9 June 2008), p. 414.

[106] As discussed below, HEU-fueled research reactors regulated by the Nuclear Regulatory Commission are exempted from this requirement.

[107] For discussions of the results of some of these tests from a non-government watchdog organization, see, for example, U.S. Nuclear Weapons Complex: Y-12 and Oak Ridge National Labora-

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.[108]

Nevertheless, as the Air Force incidents described above make clear, significant controversies continue to arise about the adequacy of nuclear security—and especially security culture—in the United States. Realistic testing of the performance of nuclear security systems against well-equipped and well-trained adversaries have repeatedly revealed serious vulnerabilities in physical protection and accounting systems for nuclear material in the U.S. nuclear complex.[109] Controversy continues to swirl, for example, over the adequacy and danger of security measures at Lawrence Livermore National Laboratory, where simulated attackers easily overcame the defenses in a 2008 red team exercise, and at the Los Alamos National Laboratory, where repeated security lapses and a failure to correct problems with security culture led to the firing of NNSA Administrator Linton Brooks in early 2007.[110] A number of the major security initiatives DOE is now undertaking—particularly the consolidation of nuclear materials into fewer, more secure locations—have been slowed by opponents who question their cost and value.[111]

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tory at High Risk, 16 October 2006 available at http://www.pogo.org/pogo-files/reports/nuclear-security-safety/Y-12/nss-y12-20061016.html as of 11 November 2008. The U.S. approach to such testing is by no means perfect, and has been criticized both by those receiving the tests (who often argue, among other things, that they assume an unrealistic level of insider knowledge of security vulnerabilities) and for presenting an unrealistically positive impression (in part because the tests are done with a substantial period of advance notice, and hence are not necessary reflective of day-to-day security performance in response to a surprise attack). Prior to 9/11, for example, the NRC allowed reactors to beef up their security forces for the day of the test, and then not to maintain those heightened defenses after the test; nevertheless, in a large fraction of the tests, the defenders failed to protect the reactor. See {U.S. Congress, 2003, GAO-NRC-sabotage} There have also been allegations of cheating on such tests over the years—for example by giving the defenders advance knowledge of the tactics the attackers would use, or by disabling the test gear so that it was unable to detect when a defender received a simulated fatal gunshot, making the defenders essentially invulnerable. See, for example, U.S. Department of Energy, Inspector General, *Protective Force Performance Test Improprieties*, DOE/IG-0636 (Washington, D.C.: DOE, January 2004, available at http://www.ig.energy.gov/documents/CalendarYear2004/ig-0636.pdf as of 8 August 2008).

[108] 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 8 July 2008).

[109] 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 4 December 2006). 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 18 June 2008). 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: 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 8 July 2008).

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

[111] See *A Review of Security Initiatives at DOE Nuclear Facilities*.

Moreover, 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. Lightly irradiated HEU is exempt from nearly all of the NRC's security requirements. Fortunately, these reactors generally never have more than a couple of kilograms of unirradiated HEU on-site at any given time, though they may have tens of kilograms of irradiated material on-site, and much of this irradiated material is still very highly enriched, and may not be radioactive enough to prevent theft by determined terrorists.[112] Tons of HEU metal—the easiest material in the world for terrorists to use to make a nuclear bomb—exists at two NRC-licensed facilities that are required to defend against a far smaller and less capable DBT than would be required at DOE sites handling the same material.[113] The NRC has ruled that reactors using plutonium in MOX fuel can be exempted from a substantial fraction of the security requirements that are required at other sites with weapons-usable nuclear material, arguing that there is "no rational reason" why a reactor with potential nuclear bomb material on-site should have any more security than any other reactor.[114] DOE's security rules exempt from major security requirements a wide range of types of material that pose serious security risks from some major security requirements, including most HEU research reactor fuel. DOE's rules define any material that has less than 10 percent by weight U-235 as falling outside Category I, the category requiring the most stringent security measures.[115]

Table 2.1 summarizes the status of efforts to strengthen nuclear security in these different categories of countries.

Consolidating Nuclear Stockpiles

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. Hence, consolidating nuclear weapons and materials at fewer sites is an absolutely critical element of nuclear security. With fewer sites to protect, greater security can be achieved at lower cost, and there are fewer teams of insiders with access to the stockpiles and fewer opportunities for mistakes to lead to critical security vulnerabilities. It is particularly important to remove material from the most vulnerable and difficult-to-defend sites—such as university campuses—where it is never likely to be possible to put in place and sustain the kind of security required for the essential ingredients

[112] 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. 36-37.

[113] 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*.

[114] U.S. Nuclear Regulatory Commission, *In the Matter of Duke Energy Corporation (Catawba Nuclear Station, Units 1 and 2)*, CLI-04-29 (Washington, D.C.: NRC, 2004; available at http://www.nrc.gov/reading-rm/doc-collections/commission/orders/2004/2004-29cli.pdf as of 22 September 2006); U.S. Nuclear Regulatory Commission, *NRC Authorizes Use of Mixed Oxide Fuel Assemblies at Catawba Nuclear Power Plant* (Washington, D.C.: NRC, 2005; available at http://www.nrc.gov/reading-rm/doc-collections/news/2005/05-043.html as of 30 December 2006).

[115] For the specifics of categorizing different types of material, current DOE orders still refer back to U.S. Department of Energy, *Guide to Implementation of DOE 5633.3b, "Control and Accountability of Nuclear Materials"* (Washington, D.C.: DOE, 1995).

Table 2.1: Strengthening Nuclear Security: Progress by Category of Country

Category	Assessment
Russia	Dramatic progress, though major issues remain. Planned U.S.-sponsored security upgrades for both warhead sites and nuclear material buildings almost complete, though some warhead sites and material buildings not covered. Inadequate Russian investment to ensure sustainability, though signs of improvement. Questions on security culture. Poorly paid and trained conscript guards for nuclear material. Substantial threats from widespread insider corruption and theft. Substantial outsider threats as well, though suppressed by counterinsurgency in Chechnya.
Developing states with nuclear weapons (Pakistan, India, China, North Korea)	Progress in some areas, not in others. Significant cooperation with Pakistan, but specifics classified. Severe threats in Pakistan from nuclear insiders with jihadist sympathies, al Qaeda or Taliban outsider attacks, and a weak state. India has so far rejected nuclear security cooperation. Broad dialogue with China, but little evidence yet that this has led to substantial improvements on the ground. No effort yet to engage with North Korea on nuclear security cooperation, but very small stock and garrison state probably limit risks of nuclear theft.
Developing and transition non-nuclear-weapon states	Some progress. Upgrades completed at nearly all facilities with weapons-usable material in the Eurasian states outside of Russia, and in Eastern Europe. Belarus, Ukraine, and South Africa have particularly dangerous nuclear material: upgrades completed in Ukraine (though sustainability is an issue); upgrades nearing completion after a several-year delay in Belarus; South Africa hosted an IAEA security review team after the Pelindaba break-in, but has declined nuclear security cooperation with the United States. Upgrades completed for nearly all HEU-fueled research reactors that previously did not meet IAEA recommendations, but most upgrades would not be enough to defend against demonstrated terrorist and criminal capabilities.
Developed Countries	Some progress. Several countries have strengthened nuclear security rules since 9/11. The United States has ongoing dialogues with key countries on nuclear security, but does not sponsor security upgrades in wealthy countries. Nuclear security requirements in some countries remain insufficient to protect against demonstrated terrorist or criminal threats. The Global Initiative to Combat Nuclear Terrorism and the newly established World Institute for Nuclear Security (WINS) may provide fora for discussing nuclear security improvements in developed countries.
United States	Substantial progress, though issues remain. DOE has drastically strengthened its requirements for protecting both nuclear weapons and materials (especially from outsider attack) since 9/11. NRC has also increased its security requirements, though requirements for NRC-regulated facilities with large quantities of HEU are far below those at DOE. NRC-regulated research reactors fueled with HEU remain exempted from most NRC security requirements.

Source: Author's estimates.

of nuclear weapons.[116]

[116] For a useful discussion of the advantages of removing material from many sites rather than relying on upgraded security at all existing sites, see William Potter, "Nuclear Terrorism and the Global Politics of Civilian HEU Elimination," *The Nonprolif-*

Major steps should be taken to consolidate nuclear warhead stockpiles, military plutonium and HEU stockpiles, and civilian plutonium and HEU stockpiles. At present, however, the only major U.S. programs related to consolidation focus on (a) civilian HEU stockpiles and (b) plutonium and HEU stockpiles within DOE's nuclear complex. No significant programs are underway to consolidate nuclear warheads to fewer sites, or to reduce civilian use of separated plutonium or the massive and growing civilian separated plutonium stockpiles.[117]

In both the areas where programs are underway, as described below, significant progress is being made, though much more remains to be done. GTRI in particular has greatly accelerated the rate at which HEU-fueled reactors are being converted to low-enriched uranium (LEU) that cannot support an explosive nuclear chain reaction, and the rate at which HEU is being removed from these sites. In the four and a half years since GTRI was founded, 23 HEU-fueled reactors on its target list have converted or shut down, compared to one in the four-and-a-half years before GTRI was founded.[118]

Nevertheless, very important gaps remain, even in the efforts to minimize use of civilian HEU, where GTRI is having its biggest impact. There has been little progress in convincing Russia to convert its HEU-fueled research reactors, the world's largest fleet, or to shut them down. The operators of many HEU-fueled research reactors have little interest in converting or shutting down and giving up the HEU at their sites. New approaches to providing targeted packages of incentives, bringing together the capabilities of multiple agencies, are likely to be necessary to convince them.[119] In many cases, sustained high-level political intervention may be necessary, as it is not likely to be possible to resolve the issues at the level of technical experts. Ukraine, for example, agreed in principle to blend down all its HEU—including one of the few stocks in developing or transition countries that includes enough high-quality HEU for a gun-type bomb—during an April 2008 visit by President Bush, following repeated U.S. interventions with Ukrainian cabinet ministers, the Ukrainian prime minister, and the Ukrainian president.[120] Belarus and South Africa each have sites that also have more than enough HEU for a gun-type bomb, but as of October 2008, no agreement to remove these stocks had been reached with either country – though reactors in both Ukraine and South Africa have recently been converted to LEU fuel. Similarly, although Kazakh Presi-

eration Review, Vol. 15, No. 2, July 2008, pp.135-158. Potter's article is the lead-in for an excellent special section of *Nonproliferation Review* on minimizing civil use of HEU worldwide.

[117] The Cooperative Threat Reduction program does provide assistance to Russia for transporting nuclear weapons to dismantlement sites or secure central storage facilities; in some cases, these transports may contribute to closing out particular nuclear weapon storage sites entirely, but this has not been a key focus of the effort

[118] Data provided by NNSA, October 2008.

[119] For discussion, see, for example, Christina Hansell, "Practical Steps Toward a World Without Civilian HEU," *Nonproliferation Review,* Vol. 15, No. 2, July 2008, pp. 289-310.

[120] The document signed during President Bush's visit, "Priorities for U.S.-Ukraine Cooperation," indicates that "both countries intend to cooperate to consolidate and subsequently downblend all highly enriched uranium in Ukraine for domestic use." NNSA is now working to convert this expression of intention into action on the ground. Information provided by NNSA, October 2008. For a useful, though somewhat dated, discussion of the Ukraine and Belarus cases, see William C. Potter and Robert Nurick, "The Hard Cases: Eliminating Civil HEU in Ukraine and Belarus," *Nonproliferation Review* 15, no. 2 (July 2008). This article is largely based on interviews conducted some years ago, and does not include much of the fairly sustained effort in recent years that led to the recent agreement.

dent Nursultan Nazarbayev has publicly agreed to get rid of all HEU in Kazakhstan, efforts to remove the HEU from the Alatau site are not complete, despite years of effort.[121]

In many cases, it is likely to be cheaper and quicker to give underutilized HEU-fueled reactors incentives to shut down, rather than attempting to convert them, but there is still no shut-down incentive program, either sponsored by the United States or others.[122] By passing the Burr Amendment weakening U.S. controls on exports of HEU for production of medical isotopes, the Congress took away much of the incentive producers had to shift to production using LEU, and there has since been little progress in convincing the major producers to convert.[123]

121 For Nazarbayev's statement, see Ethan Wilensky-Lanford, "Kazakhstan Says End of Bomb-Grade Uranium is in Sight," New York Times, 9 October 2005. For a description of the plan to remove all HEU from Alatau, see U.S. Department of Energy, National Nuclear Security Administration, "U.S. Department of Energy and NTI Announce Key Nonproliferation Project With Kazakhstan" (Washington, D.C.: NNSA, 29 September 2006), available at http://www.energy.gov/news/4197.htm as of 12 November 2008

122 Even in the absence of any incentives, far more HEU-fueled reactors have shut down than have converted since U.S.-sponsored conversion programs began in 1978, suggesting the potential power of the shut-down approach as a complement to conversion. See Ole Reistad and Styrkaar Hustveit, "Appendix II: Operational, Shut Down, and Converted HEU-Fueled Research Reactors," *Nonproliferation Review* 15, no. 2 (July 2008; available at http://cns.miis.edu/pubs/npr/vol15/152_reistad_appendix2.pdf as of 3 July 2008).

123 See, for example, Cristina Hansell, "Nuclear Medicine's Double Hazard: Imperiled Treatment and the Risk of Terrorism," *Nonproliferation Review,* Vol. 15, No. 2, July 2008, pp. 185-208. For an interesting account of the lobbying behind this change in the law, 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.

The paragraphs below summarize the current state of progress in consolidation efforts, based on country categories similar to those described above for security upgrades.

Russia

Some progress has been made in consolidating Russia's stockpiles of nuclear weapons and weapons-usable nuclear materials, but little further progress appears to be forthcoming in the near term. The Soviet Union and later Russia substantially reduced the number of sites where nuclear weapons are stored when nuclear weapons were pulled out of Eastern Europe and the non-Russian states of the former Soviet Union, and pulled out of most front-line tactical deployment sites. But there are still scores of nuclear warhead storage sites in Russia, by far 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.[124] Indeed, at U.S. insistence, Russia has agreed not to close any nuclear warhead storage site that receives DOD-funded security upgrades for at least three years after the upgrades are completed, creating, in effective, a commitment not to consolidate these stockpiles in the next few years.[125]

124 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 9 July 2007), p. 19.

125 This was agreed because of concerns that U.S. support for security upgrades would be wasted if those sites were closed shortly after the upgrades

Similarly, Russia has the world's largest number of buildings with weapons-usable nuclear material, estimated at nearly 250 buildings spread amongst 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. Russia has ended nuclear weapons assembly and disassembly activities at two of the four sites that used to do this work, and has ended nuclear weapons component fabrication at one of the two facilities that used to do that work, and in addition, with NNSA's help, Russia has ended plutonium production at Seversk in the first half of 2008,[126] leaving only one remaining plutonium production reactor at Zheleznogorsk, which is to be shut by 2010. Since the two reactors shut down at Seversk not only produced hundreds of kilograms of plutonium every year, but also used hundreds of kilograms of HEU in thousands of small, easily carried fuel elements, which had to be fabricated and transported every year, this shut-down is an important consolidation step. 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 10 tons of HEU blended by April 2008).[127] 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 rarely-utilized research reactors in Russia. As nearly half of the world's HEU-fueled research reactors are in Russia, this is a major issue.[128] Indeed, although GTRI recently expanded the list of reactors it will attempt to convert, there are still 78 research and icebreaker reactors that it is not planning to attempt to address (more than half of the remaining HEU-fueled civilian reactors in the world), and 68 of these are in Russia (with nearly all of the remainder in the United States).[129] Even if HEU minimization efforts succeed elsewhere, if they do not succeed in Russia, widespread civilian HEU use there will still pose serious dangers of nuclear theft. Recently, Russia has agreed to carry out U.S.-funded feasibility studies on conversion of six Russian reactors;[130] this could conceivably be the prelude to serious Rus-

were done. 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.

126 U.S. Department of Energy, National Nuclear Security Administration, "NNSA Announces the End of Plutonium Production in Seversk, Russia" (Washington, D.C.: NNSA, 5 June 2008, available at http://nnsa.energy.gov/news/2041.htm) as of 6 July 2008.

127 U.S. Department of Energy, National Nuclear Security Administration, "U.S. and Russia Cooperate to Eliminate Dangerous Nuclear Material" (Washington, D.C.: NNSA, 24 April 2008, available as of 7 July 2008 at http://nnsa.energy.gov/news/1987.htm).

128 Elena K. Sokova, "Phasing out Civilian HEU in Russia: Opportunities and Challenges," *Nonproliferation Review* 15, no. 2 (July 2008).

129 Data provided by NNSA, June 2008.

130 Interviews with NNSA officials, July 2008. The six reactors are the IR-8, OR, and Argus reactors at the Kurchatov Institute of Atomic Energy in Moscow; the IRT-2000 reactor at the Moscow Engineering Physics Institute; the MIR reactor at the Institute of Atomic Reactors at Dmitrovgrad; and the IRT-T at Tomsk Polytechnic University. (Personal communication from Frank von Hippel, July 2008.)

sian consideration of a large-scale effort to minimize use of civilian HEU in Russia, but that remains to be seen.

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 power reactor (which currently operates with HEU in the range of 22-27 percent enrichment) and the larger BN-800 fast neutron reactor now under construction. This may ultimately mean a further spread, rather than contraction, in the number of sites with large quantities of weapons-usable materials.

Developing states with large nuclear programs (Pakistan, India, China)

Pakistan, India, and China all have nuclear complexes which, while large by developing world standards, are tiny by comparison to those of the United States and Russia, and include only small numbers of sites with nuclear weapons or weapons-usable materials, making consolidation somewhat less critical in their cases. Only modest progress toward greater consolidation has been made in any of these countries. To date, China does not appear to have dispersed its nuclear forces to a larger number of locations in response to concerns over U.S. offensive and defensive strategic capabilities, though China is developing mobile nuclear missiles. If China's nuclear arsenal grows and diversifies in the future, it may be stored at a larger number of nuclear sites. Growing nuclear arsenals in India and Pakistan may someday be stored at a larger number of sites as well. China recently began participating in efforts to convert HEU-fueled research reactors, and conversion planning is now underway for the Chinese-supplied Miniature Neutron Source Reactors (MNSRs), each of which has just under a kilogram of HEU in its core. China shut down one of its own MNSRs in 2007, and converted two steady-state research reactors and a critical assembly, also in 2007.[131] India is planning to convert its 50-year-old Apsara research reactor to LEU fuel without U.S. help, though when this will occur remains unclear.[132] Pakistan's single research reactor has been converted to LEU, though some irradiated HEU fuel remains on-site. Both India and Pakistan are expanding their nuclear weapons stockpiles, but neither appears to be dispersing those stockpiles at larger numbers of sites.

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.[133]

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[131] Reistad and Hustveit, "Appendix II."

[132] See Srikumar Banerjee (director, Bhabha Atomic Research Centre), "Founder's Day Address—2006," 30 October 2006, available as of 6 July 2008 at http://www.barc.ernet.in/talks/fddir06.html. This has been planned for at least a decade, however, without the plan actually having been implemented.

[133] 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, available at http://www.armscontrol.org/projects/india/20070803_123.asp as of 6 July 2008).

Developing and transition states with small programs

North Korea is the only developing state with a very small nuclear infrastructure that also has nuclear weapons. While North Korea has signed six-party statements committing it to abandon "all" of its nuclear programs and achieve a nuclear-weapon-free Korean peninsula, whether it will go beyond disabling production facilities to giving up the weapons and plutonium that it already has—and if so, at what price—remains unclear. Successful North Korean denuclearization would clearly be a dramatic victory for nonproliferation, and would represent a major consolidation of nuclear weapon stockpiles. North Korea also has a Soviet-supplied, HEU-fueled IRT-type research reactor (which is rarely used, because of insufficient fuel and funds).[134] An estimated 42 kilograms of irradiated HEU (a mix of material that was originally 80 percent and 36 percent enriched) is at this site. While there may be useful purposes for which this reactor could be used in the future,[135] it should be converted to LEU fuel.

Other developing and transition states with small nuclear programs are non-nuclear-weapon states; typically their only HEU or separated plutonium is associated with one or a few HEU-fueled research reactors. NNSA's GTRI program has been working with the IAEA and other countries to help convert these reactors and remove their HEU, and approximately 15 reactors in these countries have converted to LEU. All of the HEU has been removed from Argentina, Brazil, Columbia, the Philippines, Slovenia, and Thailand,[136] and additional countries are expected to join this list as conversion and HEU-removal efforts proceed.

GTRI currently plans to remove all but a handful of stocks of U.S.-origin HEU from developing and transition countries. This includes both a long-standing offer to take back U.S.-origin HEU that fits in particular categories making it relatively straightforward for the United States to manage once it is returned, and a new "gap materials" effort that addresses other potentially vulnerable HEU or plutonium that does not meet these eligibility requirements (and therefore falls into "gaps" between other programs).[137] The exceptions are cases where political obstacles block cooperation (such as the small stock of irradiated U.S.-origin HEU that still exists in Iran), or where the relevant states have not yet agreed to send the material back.[138]

GTRI currently plans to help remove all Soviet-supplied HEU from sites outside of Russia, and has maintained a substantial schedule of shipments of both fresh and irradiated HEU to secure sites in Russia, where the material is blended to LEU.

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[134] See, for example, David Albright, "Phased International Cooperation with North Korea's Civil Nuclear Programs" (Washington, D.C., Institute for Science and International Security, 19 March 2007, available online at http://www.isis-online.org/publications/dprk/CivilNuclearNK.pdf as of 6 July 2008).

[135] See discussion in Albright, "Phased International Cooperation."

[136] See U.S. Department of Energy, National Nuclear Security Administration, "All Highly Enriched Uranium Removed from Latvia " (Washington, D.C.: NNSA, 16 May 2008; available at http://nnsa.energy.gov/2006.htm as of 3 July 2008). Chile has sent back all of its U.S.-origin HEU, but has additional non-eligible HEU that NNSA hopes to remove in the future in its "gap" materials effort. Data provided by NNSA, June 2008.

[137] For a discussion of both the take-back program for eligible U.S.-origin materials and the gap materials program, see U.S. Department of Energy, National Nuclear Security Administration, *Strategic Plan: Reducing Nuclear and Radiological Threats Worldwide* (Washington, D.C.: DOE, 2007).

[138] Data provided by NNSA, June 2008.

Table 2.2: U.S. Assisted Removals of Russian-Origin HEU Fuel

Location	Date	Material Removed
Ulba Metallurgical Plant, Ust-Kamenogorsk, Kazakhstan	Nov 1994	581 kg HEU (fresh)
E. Andronikashvili Inst. of Physics, Mtskheta, Georgia	Apr 1998	~5kg HEU (fresh+irradiated)
Vinca Inst. of Nuclear Sciences, Serbia	Aug 2002	48 kg HEU (fresh)
Inst. for Nuclear Research, Pitesti, Romania	Sep 2003	14 kg HEU (fresh)
Inst. for Nuclear Research and Nuclear Energy, Sofia, Bulgaria	Dec 2003	~17 kg HEU (fresh)
Tajura Nuclear Research Center, Libya	Mar 2004	16 kg HEU (fresh)
Inst. of Nuclear Physics, Uzbekistan	Sep 2004	~3 kg HEU (fresh)
Nuclear Research Inst., Rez, Czech Republic	Dec 2004	6 kg HEU (fresh)
Salaspils Research Reactor, Latvia	May 2005	~3 kg HEU (fresh)
Czech Technical University, Czech Republic	Sep 2005	14 kg HEU (fresh)
Inst. of Nuclear Physics, Uzbekistan	Apr 2006	63 kg HEU (irradiated)
Tajura Nuclear Research Center, Libya	July 2006	3 kg HEU (fresh)
MARIA, Inst. for Atomic Energy, Poland	Aug 2006	40 kg HEU (fresh)
Rossendorf Research Center, Germany	Dec 2006	268 kg HEU (fresh)
MARIA, Inst. for Atomic Energy, Poland	Aug 2007	~9 kg HEU (fresh)
Dalat Nuclear Research Inst., Vietnam	Sep 2007	~4 kg HEU (fresh)
Nuclear Research Inst., Rez, Czech Republic	Dec 2007	80 kg HEU (irradiated)
Salaspils Research Reactor, Latvia	May 2008	~14 kg HEU (irradiated)
Inst. for Nuclear Research and Nuclear Energy, Sofia, Bulgaria	July 2008	~6 kg HEU (irradiated)
Budapest Research Reactor, Hungary	Sep 2008	~154 kg HEU (irradiated)

Source: Data provided by *Securing the Bomb 2007* and provided by NNSA, July-October 2008

(See Table 2.2.) Earlier plans to remove all of the fresh HEU by the end of 2005 have not been realized. Two of the sites with the most substantial and readily weapons-usable stockpiles of HEU, however, at Kharkiv in Ukraine and at Sosny in Belarus, have strongly resisted giving up their HEU—though as noted earlier, in April 2008 Ukraine agreed in principle to blend down all HEU in Ukraine.[139] Kazakhstan, as noted above, has also been dragging its feet on addressing the significant stock of HEU at its Alatau site, despite agreements in principle to do so. Similarly, South Africa has not agreed to give up the large stock of HEU at the Pelindaba site, most of which is of South African origin, despite the November 2007 intrusion at Pelindaba. Although South Africa has converted the Safari-1 reactor to LEU fuel, the reactor still uses HEU targets to produce medical isotopes, and the South Africans argue that the large HEU stockpile there may be needed in the future for use in targets for the production of medical isotopes.[140] These three sites likely have the largest stockpiles of HEU in developing or transition non-nuclear-weapon states, and pose particular dangers. Additional incentives and high-level political interventions are likely to be needed to convince these countries and sites that it is in their interest to eliminate the HEU at these sites.

Developed countries

As noted above, stockpiles of nuclear weapons and materials in developed countries—including the United States—

[139] For useful but somewhat dated account of these cases, which does not include the April 2008 agreement in principle or the several high-level interventions that contributed to it, see William C Potter and Robert Nurick, "The Hard Cases: Eliminating Civil HEU in Ukraine and Belarus," Nonproliferation Review 15, no. 2 (July 2008).

[140] Interview with NNSA officials, July 2007. NNSA confirmed in October 2008 that agreement with South Africa on eliminating these stocks had not yet been reached.

also pose significant risks of nuclear theft, in some cases. There are many more sites with HEU or separated plutonium in these countries than there are in developing or transition states, and these sites often larger amounts of material on-site. Developed countries with substantial stocks include both nuclear-weapon states such as Britain and France and non-nuclear-weapon states such as Canada, Germany, and Japan.

NNSA appears to be of two minds about the threat posed by HEU in these countries; they have focused considerable effort on converting reactors in these countries to LEU, but do not plan to return much of the irradiated HEU from these countries to the United States, assuming (often without detailed site-by-site security assessments) that because it is in wealthy countries it is already secure or already has an appropriate disposition path (the principal alternative path to return to the United States currently being reprocessing in France).[141] GTRI plans to take back less than a fifth of the 15.9 tons of U.S.-origin HEU in foreign countries[142]—and much of the material that is being taken back is from developing countries, so only a very small fraction of the material in developed states is expected to return. The amount of eligible U.S.-origin HEU NNSA is planning to bring back to the United States has actually shrunk since GTRI was established.[143] GTRI's "gap materials" program, however, has returned well over 100 kilograms of fresh, unirradiated HEU from developed countries such as Belgium, Canada, and the Netherlands (largely in cases where these countries were willing to bear the cost of removing these materials).

As might be expected given the low priority NNSA has placed on removing materials from developed countries, progress in consolidating these countries' stockpiles has been mixed at best. France and Britain have both reduced their comparatively small nuclear weapon stockpiles, and the number of locations where these stockpiles exist, in recent years. Neither appears to plan further consolidation. There is no indication that Israel plans any reduction in or consolidation of its nuclear stockpile.

Most of the more than 50 HEU-fueled reactors that have converted to LEU fuel

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141 See, for example, U.S. Department of Energy, *FY 2009 NNSA Budget Request*, p. 531. There are also legal constraints on taking back HEU that is not of types covered by the 1996 renewal of the U.S. take-back offer, and were therefore not covered in the accompanying environmental impact statement. NNSA is undertaking an environmental assessment to make it possible to take back modest quantities of material beyond the 1996 offer.

142 NNSA only plans to return 1.3 tons of eligible U.S.-origin HEU, but also plans to return some U.S.-origin HEU in the "gap" program. If *all* of the planned material to be removed in the gap program were U.S.-origin HEU (which is not the case), the total would still be in the range of 15 percent of the total amount of U.S.-origin HEU abroad, leaving the vast majority of the U.S.-origin HEU where it is. Data provided by NNSA, August 2007. NNSA confirmed in June 2008 that its estimates have not changed substantially since then.

143 When GTRI was established, DOE was hoping to bring back most of the eligible U.S.-origin HEU, though experts expected that roughly half might not be returned—still significantly more than expected under current GTRI plans. GAO and DOE Inspector General investigators recommended providing additional incentives so that more of this material would be returned, not cutting back the amount that would be returned. See 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); 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).

are in the United States or other developed countries. Similarly, most of the more than 100 HEU-fueled reactors that have shut down since 1978 are in the United States, Russia, or other developed countries.[144] As discussed in more detail below, GTRI and its predecessor programs have helped remove all of the HEU from several of these reactors, and others have likely acted independently to send their HEU to France for reprocessing. Developed countries that have eliminated all their civilian HEU include Greece, Italy, Portugal, South Korea, Spain, and Sweden.[145] Nevertheless, civilian HEU continues to exist at scores of sites in developed countries, and under current plans will continue to do so into the indefinite future. Most of the world's HEU-fueled reactors outside of the United States and Russia are in these countries, and while GTRI has plans to attempt to convert most of them, the schedule for this effort stretches to 2018;[146] perhaps more important, many of these facilities have no interest in converting or shutting down, and currently plan to continue to use HEU fuel indefinitely. Some of these sites have substantial stocks of HEU—particularly when irradiated HEU fuel, which also poses important nuclear theft risks, is included. (Research reactor fuel elements are typically small enough to be easily carried, and are far less radioactive than massive power-reactor fuel assemblies; the radiation levels from research reactor fuel elements after a few years of cooling are typically far less than would be necessary to prevent nuclear theft by determined terrorists. If the fresh fuel was 90 percent enriched, the irradiated fuel is typically still 80 percent enriched or more, and the relatively simple chemical steps required to extract the uranium from the fuel are identical to those needed to get the uranium out of fresh, unirradiated fuel.[147])

Three of the four major producers of medical isotopes, all of whom use HEU targets to produce these isotopes, are also in developed countries (Canada, Belgium, and the Netherlands), using tens of kilograms of weapon-grade HEU every year.[148] Because the targets are only very lightly irradiated, huge quantities of weapon-grade HEU that is only weakly radioactive are building up in the "waste" stores at these producers' sites. Although technologies have been developed that make it possible to produce these isotopes with LEU, these producers have resisted converting. In early 2008, Atomic Energy of Canada, Limited (AECL) canceled construction of the MAPLE reactors, which had been intended to replace the 50-year-old NRU reactor in producing medical isotopes using HEU targets; the need to find other means to produce these isotopes before the end of the NRU's operable lifetime may incline Canada more favorably to considering LEU options. But as noted above, the Burr amendment has taken away much of these producers' incentive to convert to LEU. Some facilities in the United States and elsewhere are considering options to compete with the

[144] Reistad and Hustveit, "Appendix II."

[145] See U.S. Department of Energy, National Nuclear Security Administration, "NNSA Completes Successful Year of U.S.-Origin Nuclear Fuel Returns" (Washington, D.C.: NNSA, 7 October 2008; available at http://www.nnsa.energy.gov/news/2173.htm as of 14 October 2008), and U.S. Department of Energy, "All Highly Enriched Uranium Removed from Latvia." Denmark has sent back all of its HEU eligible for the U.S. take-back program, but has additional non-eligible HEU that NNSA hopes to remove in the future in the "gap" materials effort. Data provided by NNSA, June 2008.

[146] U.S. Department of Energy, *FY 2009 NNSA Budget Request*, p. 531.

[147] See, for example, discussion in Bunn and Wier, *Securing the Bomb: An Agenda for Action*, pp. 36-37.

[148] The fourth is in South Africa, discussed above. For discussion, see Hansell, "Nuclear Medicine's Double Hazard."

major suppliers for the medical isotope production market with technologies that do not use HEU, but these efforts are still at an early stage. It remains unclear when or if medical isotope production will cease relying on tens of kilograms of potential nuclear bomb material every year.[149]

Targeted packages of incentives for individual countries and facilities, programs to encourage unneeded facilities to shut down (as a complementary tool to helping facilities convert to LEU), and higher-level political intervention are likely to be needed if the dangers posed by these HEU stockpiles are to be successfully addressed. GTRI has been working to develop incentives packages to encourage some facilities to allow their fuel to be removed, but has been hemmed in by limited budgets.

Civilian separated plutonium is also a major issue in some developed countries. The two developed nuclear-weapon states outside of the United States and Russia, Britain and France, both have huge plutonium reprocessing plants and stockpiles of tens of tons of civilian plutonium. France uses reactor-grade plutonium-uranium mixed oxide (MOX) fuel in a large number of its own power reactors, and fabricates such fuel for other countries as well. Britain also has a MOX fuel fabrication plant, though the plant has never worked well and was intended only to serve foreign customers, since Britain does not use MOX fuel in its own reactors. (Reactor-grade plutonium, like weapon-grade plutonium, is usable in nuclear explosives.)[150] Non-nuclear-weapon states such as Germany, Switzerland, and Belgium have also made extensive use of MOX fuel (and Belgium had a recently-closed MOX fabrication plant), but these programs appear to be declining. Japan, by contrast, has just opened its large reprocessing plant at Rokkasho-Mura, and plans to begin using MOX fuel to burn off some of its growing stockpiles of separated plutonium. This use of plutonium-based fuel 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—though as cheap dry cask storage technology becomes more widely available, Britain, France, and Russia are all experiencing declines in the number of utilities willing to pay the price of reprocessing. Britain has announced that it will close its reprocessing plant when existing contracts are complete (approximately 2012); Japan's plant may turn out to be the last large reprocessing plant built anywhere in the world for many years to come, although reprocessing enthusiasts in the United States, Russia, China, and India are all proposing new facilities. The new U.S. focus on reprocessing as a central element of the future of nuclear energy, as part of the Global Nuclear Energy Partnership (GNEP), however, appears to be encouraging renewed interest in reprocessing and related technologies.

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[149] In the United States in particular, the Missouri University Research Reactor (MURR) is considering large-scale production, and the commercial firm BWXT is developing technology for producing isotopes in a solution reactor which would not require HEU. See, for example, discussion in Hansell, "Nuclear Medicine's Double Hazard." In the Burr amendment, Congress called for a National Academy of Sciences study on options for producing medical isotopes without HEU; that study should be reporting in late 2008.

[150] 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.

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 small number of locations.[151] Part of this was the result of the 1991-1992 Presidential Nuclear Initiatives.[152] 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 stocks of weapons-usable nuclear material requiring substantial security measures have been removed from the Sandia National Laboratory.[153] Under current plans, removing all potential nuclear bomb material from Hanford, Livermore, and Los Alamos will take somewhat longer, but NNSA hopes to have only five sites with weapons-usable material remaining in its nuclear-weapons complex by 2012. 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.[154]

DOE has also recently resumed funding the 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 the reactor at Purdue was converted in 2007 and the reactors at Washington State and Oregon State were converted in 2008.[155] At the same time, however, disposition of excess plutonium will add

[151] 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 7 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).

[152] 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).

[153] U.S. Department of Energy, National Nuclear Security Administration, "First Phase of Nuclear Material Consolidation Complete: Work Completed at Sandia Seven Months Ahead of Schedule" (Washington, D.C.: 28 February 2008, available as of 6 July 2008 at http://nnsa.energy.gov/news/1800.htm).

[154] Peter Stockton and Frank von Hippel, "Fissile Material Consolidation in the U.S. Nuclear Complex," in International Panel on Fissile Materials, *Global Fissile Material 2007: Second Report of the International Panel on Fissile Materials* (Princeton, N.J.: Program on Science and Global Security, Princeton University, 2007; available at http://www.fissilematerials.org/ipfm/site_down/gfmr07.pdf as of 3 July 2008), pp. 43-55.

[155] U.S. Department of Energy, National Nuclear Security Administration, "NNSA, Oregon State University, and Washington State University Complete the Conversion of Two U.S. Research Reactors" 2 October 2008, available as of 14 October 2008 at http://nnsa.energy.gov/news/2170.htm and "NNSA Successfully Converts Third Domestic Research Reactor in the Last Year," 13 September 2007,

Table 2.3: Consolidating Nuclear Stockpiles: Progress by Category of Country

Category	Assessment
Russia	Limited progress, major obstacles. Nuclear weapon sites reduced during 1980s-1990s pullbacks – but nuclear weapons continue to be stored at dozens of separate sites, with no apparent movement toward further consolidation. Russia has the world's largest number of HEU-fueled research reactors, and has largely refused to engage on converting them to LEU or shutting them down. The Russian Navy has greatly reduced its sites with HEU, and at least one facility has given up all its HEU as part of the Materials Consolidation and Conversion program. Russia has closed down nuclear weapons work at several sites, and some of the remaining sites have moved nuclear material into a smaller number of buildings. But potential bomb material still exists in over 200 buildings, and the Russian government appears unwilling to pursue large-scale consolidation.
Developing states with nuclear weapons (Pakistan, India, China, North Korea)	Limited progress – but these countries have small nuclear stockpiles at small numbers of sites, so less consolidation is needed. China has joined the reactor conversion effort and has converted three research reactors and shut down one more. India is planning to convert one HEU-fueled research reactor to LEU without U.S. help. Growing nuclear arsenals may be stored at larger number of sites in the future. China and India are both pursuing civilian plutonium programs that may eventually lead to widespread use of plutonium fuels.
Developing and transition non-nuclear-weapon states	Substantial progress, but a great deal more to be done. GTRI has accelerated the pace of converting HEU-fueled research reactors to LEU and of shipping Soviet-supplied HEU back to secure sites in Russia; the pace of returning U.S.-supplied HEU has not increased, however. Twelve U.S.-supplied countries and four Soviet-supplied countries (Latvia, Georgia, Iraq, and Bulgaria) have had all their HEU removed. Ukraine has a particularly dangerous stockpile of HEU, which it has agreed in principle to downblend. Belarus and South Africa, which also have particularly dangerous HEU stockpiles, have not yet agreed to eliminate those stocks. Reactors in Ukraine and South Africa have been converted to LEU fuel.
Developed Countries	Some progress, but a great deal more to be done. GTRI has accelerated the pace of converting HEU-fueled research reactors to LEU, and GTRI's "gap materials" effort has brought tens of kilograms of fresh HEU back to the United States from countries such as Canada, Belgium, and the Netherlands. Only a small portion of HEU in these countries is currently targeted for removal, however, and many facilities have little interest in giving up the use of HEU. No programs are in place to minimize the locations where plutonium fuels are used, and the current approach to the Global Nuclear Energy Partnership (GNEP) may have the opposite effect.
United States	Substantial progress, though issues remain. U.S. nuclear weapons are now stored at a small number of sites, though tactical bombs remain at several sites in Europe. NNSA is funding the conversion to LEU of several U.S. HEU-fueled reactors per year. DOE is substantially consolidating its sites and buildings with potential bomb material, though not as quickly or comprehensively as some experts have recommended. The planned MOX program for plutonium disposition would add a small number of reactors to sites with material of concern, and the current approach to GNEP, if funded, could lead to expansion of such sites.

Source: Author's estimates.

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 GNEP, if it proceeds, would 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.[156]

Progress in these consolidation efforts, and steps yet to be taken, are summarized in Table 2.3.

Building Global Policy Frameworks: Steps Taken and Work Yet to Do

In addition to helping to beef up security and accounting measures at particular sites, or to remove warheads and materials from those sites, it is crucial to put the policy frameworks in place that will make it possible to achieve effective and lasting security for nuclear stockpiles worldwide. Strong policy frameworks need to be put in place both on the international scene and within the United States. On the international scene, this section assesses efforts to: (a) build a sense of urgency about the threat of nuclear terrorism and a commitment to addressing it around the world; (b) create a fast-paced global nuclear security campaign; (c) forge effective global nuclear security standards; (d) build real nuclear security partnerships with key countries; (f) ensure that effective nuclear security measures, once put in place, will be sustained for the long haul; and (g) strengthen nuclear security culture.

Building a sense of urgency and commitment worldwide

Convincing policymakers and nuclear managers around the world that nuclear terrorism is a real and urgent threat to their countries' security, deserving substantial investments of their time and resources, is critical to success in reducing the risk. If they are convinced of this, they are likely to take the actions needed to prevent nuclear terrorism; if they are not convinced—as many are not today—they are not likely to make the major efforts that are often needed to get agreement on increased nuclear security spending, tighter nuclear security rules, more extensive nuclear counter-terrorism efforts, and the like.

In recent years, there has been some progress in convincing policymakers around the world of this reality, but there is much more to be done. Two initiatives appear to have had particularly important impacts in building the sense of urgency around nuclear terrorism. The Global Initiative to Combat Nuclear Terrorism, launched by the United States and Russia in 2006, now has 75 participating states, including all but a few of the states with substantial stockpiles of nuclear weapons or materials, and key potential transit

available as of 6 July 2008 at http://nnsa.energy.gov/news/907.htm.

[156] 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, 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).

countries. Political leaders in all these countries have accepted a very general statement of principles on the importance of preventing nuclear terrorism, creating political cover for lower-level officials in those countries to pursue cooperation to address the threat.[157] The Global Initiative, with Russia and the United States working together as co-chairs to focus efforts to prevent nuclear terrorism, has undoubtedly elevated attention to the nuclear terrorism threat in many countries. It provides an umbrella under which all aspects of preventing nuclear and radiological terrorism can in principle be discussed. Discussions of ongoing nuclear smuggling cases, of the impacts a terrorist nuclear blast would have on the private sector's ability to keep global trade moving, and of the complete inadequacy of most countries' ability to respond in the event of a major nuclear or radioactive incident have been particularly effective in convincing participants that nuclear terrorism is a real concern.[158] The Global Initiative has also scheduled a series of nuclear terrorism exercises. Involving policymakers in realistic exercises exploring how nuclear terrorism might happen and the limited options available to respond once terrorists have gotten the essential ingredients of nuclear weapons is likely to be a particularly effective way of building awareness of the threat.[159] The first such exercise, however, in Madrid in May 2008, focused on possible terrorist smuggling and use of a radioactive source for a dirty bomb—a scenario many countries find more realistic, but which may do little to increase policymakers' sense of urgency concerning protection of actual nuclear weapons, plutonium, or HEU.

In addition to the Global Initiative, in recent years U.S. intelligence agencies have reached out to key foreign intelligence agencies to discuss the nuclear terrorism threat and steps to reduce it, offering information on reports of terrorist interest in nuclear weapons and stolen nuclear material, and at least basic unclassified information on the plausibility of terrorists making a crude nuclear bomb if they got the needed nuclear material. Rolf Mowatt-Larsen, currently head of DOE's Office of Intelligence and Counter-Intelligence (and previously the lead CIA officer assigned to tracking al-Qaeda's efforts to get nuclear, chemical, biological, and radiological weapons) has been particularly active in this outreach, working with intelligence agencies in Russia, Pakistan, and allied countries such as France, Britain, and Germany.[160] Intelligence agencies often provide key input to national policy-makers concerning threats to their country, and hence convincing them that nuclear terrorism is a real and urgent threat is likely to be key to making that case to national leaders.

Unfortunately, however, many key policymakers and nuclear managers around the world continue to believe that it is unreal-

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157 Various documents on the Global Initiative can be found at U.S. Department of State, "Global Initiative to Combat Nuclear Terrorism" (Washington, D.C.: DOS, no date, available at http://www.state.gov/t/isn/c18406.htm as of 11 July 2008). For a list of participating countries, see U.S. Department of State, "Global Initiative Current Partner Nations" (Washington, D.C: DOS, 9 July 2008, available at http://www.state.gov/t/isn/105955.htm as of 11 July 2008). For details on what participants sign up to when they join the initiative, see U.S. Department of State, "Statement of Principles for the Global Initiative to Combat Nuclear Terrorism" (Washington, D.C.: DOS, 20 November 2006, available at http://www.state.gov/t/isn/rls/other/76358.htm as of 11 July 2008).

158 Interview with State Department officials, July 2008.

159 See Bunn, *Securing the Bomb 2007*, p. 104.

160 For a public discussion of some of the early efforts at such intelligence outreach with Russia and Pakistan, see Tenet, *At the Center of the Storm*, pp. 256-279. Supplemented with interviews with U.S. intelligence officials, November and December 2007.

istic that terrorists could get the essential ingredients of nuclear weapons, or make a bomb from them if they did. Former Pakistani president Pervez Musharraf's remark that making nuclear bombs was completely beyond the capacity of "men hiding in caves" is not atypical.[161] Similarly, Anatoliy Kotelnikov, then in charge of security for Russia's nuclear complex, argued in 2002 that it would be "absolutely impossible" for terrorists to make a nuclear bomb even if they got the needed nuclear material.[162] While there was undoubtedly an element of propaganda in these statements, similar views are very widespread among nuclear managers, staff, and policymakers around the world—and must be addressed if these individuals are to take the actions needed to put effective and sustainable nuclear security in place around the world.

Creating a fast-paced global nuclear security campaign

To quickly and substantially reduce the risk of nuclear theft quickly will require a fast-paced global campaign to consolidate nuclear stockpiles and upgrade security for all the remaining sites where nuclear weapons and the materials needed to make them continue to exist, extending far beyond the former Soviet Union. Some progress has been made toward this objective, but critical gaps remain. The Global Initiative has gotten many countries meeting and discussing the threat, but to date it appears to have focused more on issues such as law enforcement, radiation detection, and emergency response than on upgrading security for nuclear stockpiles.[163] The Global Partnership Against the Spread of Weapons and Materials of Mass Destruction, launched in 2002, has moved slowly, has focused almost exclusively on work in Russia and Ukraine, and has devoted little of its non-U.S. resources to upgrading security for nuclear stockpiles. At the 2008 G-8 summit, however, participants agreed that the partnership must address proliferation and terrorism risks worldwide, not just in the former Soviet Union, and listed nuclear security among the top Global Partnership priorities.[164] It remains to be seen, however, to what extent these words will be translated into deeds. To date, U.S. expenditures on upgrading nuclear security in foreign countries have dwarfed those of all other donor states combined. And most countries with nuclear stockpiles are simply not yet focused on rapid and substantial improvements in security for these stocks. In short, despite the progress in Russia and more limited progress elsewhere, the kind of fast-paced global campaign to improve nuclear security that is urgently needed simply does not yet exist.

Forging effective global nuclear security standards

Facing terrorists with global reach, nuclear security is only as good as its weakest link. Hence, effective (and effectively implemented) global standards for nuclear security are essential. The goal

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

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

[163] The Global Initiative, for example, has sponsored workshops and conferences on all these other topics, but does not appear to have sponsored major activities on issues related to improving nuclear security.

[164] See *G8 Hokkaido Toyako Summit Leaders Declaration* (Hokkaido Toyako, Japan: Group of Eight, 8 July 2008, available at http://www.g8summit.go.jp/eng/doc/doc080714__en.html as of 22 July 2008), and *Report on the G8 Global Partnership* (Hokkaido Toyako, Japan: Group of Eight, July 2008, available at http://www.g8summit.go.jp/doc/pdf/0708_12_en.pdf as of 22 July 2008).

must be to ensure that all nuclear weapons and stocks of weapons-usable nuclear materials around the world are effectively protected against the kinds of outsider and insider threats that thieves and terrorists have shown they can pose.

Unfortunately, there has been limited progress toward putting effective global standards in place. An amendment to the Convention on Physical Protection of Nuclear Materials and Facilities was agreed to in 2005, extending the convention's terms to cover materials in domestic use, storage, and transport, and to cover sabotage of nuclear facilities as well as nuclear theft. But, while containing some useful principles, the amended convention includes no particular standards for how secure nuclear material should be; it says that countries should set national rules for nuclear security, but it says nothing about what those rules should say.[165] As of mid-October 2008, only 19 countries had ratified the amendment, and it is likely to be years before it enters into force.[166] Similarly, the Convention on the Suppression of Acts of Nuclear Terrorism, also agreed to in 2005, requires parties to "make every effort to adopt appropriate measures to ensure the physical protection of radioactive materials," but says nothing about what measures would be appropriate, beyond mentioning that states should develop them "taking into account" relevant IAEA recommendations.[167] The nuclear terrorism convention entered into force in July 2007, but the number of parties to the convention remains modest. UN Security Council Resolution 1540, passed unanimously in 2004, legally requires all states to provide "appropriate effective" security and accounting for any stockpiles of nuclear weapons or related materials they may have—but to date, no one has defined what essential elements must be in place for nuclear security and accounting systems to comply with this requirement.[168]

The closest thing to a global nuclear security standard that exists today are the IAEA's recommendations on physical protection. While these are purely advisory, most states follow them, and indeed, the United States and a number of other supplier states require them to do so as a condition of bilateral nuclear supply agreements. These recommendations are much more specific than the amended physical protection convention, but they are still quite vague. For example, for "Category I" nuclear material—the type and quantity requiring the highest levels

[165] International Atomic Energy Agency, *Nuclear Security - Measures to Protect against Nuclear Terrorism: Amendment to the Convention on the Physical Protection of Nuclear Material*, GOV/INF/2005/10-GC(49)/INF/6 (Vienna: IAEA, 2005; available at http://www.iaea.org/About/Policy/GC/GC49/Documents/gc49inf-6.pdf as of 10 July 2007).

[166] See International Atomic Energy Agency, *Amendment to the Convention on the Physical Protection of Nuclear Material* (Vienna: IAEA, updated 15 October 2008, available at http://www.iaea.org/Publications/Documents/Conventions/cppnm_amend_status.pdf as of 30 October 2008). The U.S. Senate gave its advice and consent to ratification on 25 September 2008, but the United States had not yet been added to the list of parties to the amendment as of 15 October. Two-thirds of the parties to the convention, amounting to over 90 countries, must ratify the amendment before it enters into force.

[167] *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 16 September 2005). This treaty's most specific provision related to security of nuclear stockpiles is a requirement that all parties "make every effort to provide appropriate measures to ensure the protection" of nuclear and radiological materials (Article 8).

[168] For a proposed definition of essential elements for both nuclear security and nuclear accounting, see Matthew Bunn, "'Appropriate Effective' Nuclear Security and Accounting—What is It?" presentation to the Joint Global Initiative/UNSCR 1540 Workshop on "'Appropriate Effective' Material Accounting and Physical Protection," Nashville, Tenn., 18 July 2008, available at http://belfercenter.ksg.harvard.edu/publication/18452/ as of 22 July 2008.

of nuclear security—the recommendations specify that there should be a fence around the area where such material is handled, but say nothing about how difficult to penetrate that fence should be. They specify that when not in use, material should be in a locked room, but say nothing about whether a padlock that could be snapped with any bolt-cutter would be sufficient.[169] It is, in short, quite possible for a site to comply with the IAEA recommendations and still have grossly inadequate nuclear security arrangements in place. During the past year, formal international discussions of a revision to these recommendations got underway, and a small group of states (including the United States and several European countries) proposed a number of revisions that would make the text somewhat more specific—but there is no indication that these proposals would call for Category I material to be protected with high confidence against demonstrated terrorist and criminal threats, and it is likely to be years before revised recommendations are completed.

To date, it does not appear that fora such as the Global Initiative, the IAEA Office of Nuclear Security, the UNSCR 1540 Committee, or the G8 Nuclear Safety and Security Group have been used to try to develop agreed global standards for nuclear security. In short, the world is still a long way from having effective global nuclear security standards in place.

[169] 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).

Building strong nuclear security partnerships

Ultimately, substantial and lasting improvements in nuclear security can best be built through genuine partnerships, incorporating ideas and resources from all countries participating, rather than through donor-recipient relationships. Experts from the country where the nuclear stockpile whose security is to be improved exists inevitably know more about the security measures already in place and about what works and what does not in their country than foreign experts ever will. Moreover, only if the staff at nuclear facilities see new security measures as in substantial part their idea—rather than something imposed by foreigners for no good purpose—are they likely to use them appropriately and sustain them for the long haul.

In the case of Russia in particular, the beginnings of a shift toward real partnership that have been underway need to be strengthened and accelerated—despite the downturn in U.S.-Russian political relations in the aftermath of the war in Georgia. A shift from a donor-recipient relationship to a more genuine partnership is likely to be essential to the success of cooperative efforts to improve nuclear security and accounting—particularly to achieving the working-level Russian "buy-in" to the new security and accounting approaches so crucial to long-term sustainability. Substantial evidence from other types of assistance indicates that assistance programs that directly involve the recipients in all aspects of the conception, design, implementation, and evaluation of the effort have far higher success rates than those that do not.[170] To achieve a genuine partnership, Russia will have to

[170] See, for example, World Bank, *Assessing Aid: What Works, What Doesn't, and Why* (Oxford, United Kingdom: Oxford University Press, 1998).

assign more of its own resources to improving nuclear security, and change its recent practice of, in essence, not paying for anything that the United States might be convinced to pay for. The United States will have to have the flexibility to make all stages of the work truly joint efforts, with Russian experts playing key roles at every stage. [171] Russia today has plenty of money and enough expertise to provide high levels of nuclear security itself, without U.S. help. But because Russia is still not devoting the priority to nuclear security that the United States believes is needed, there is still a need for U.S. investment, in parallel with intense U.S. efforts to convince Russia to increase the priority it devotes to the subject.

The Bratislava nuclear security initiative, in which U.S. and Russian officials are jointly being held accountable by the U.S. and Russian presidents for meeting agreed nuclear security objectives on schedule, and in which the two sides have done more to describe to each other their approaches to funding and regulating nuclear security, has strengthened the sense of partnership in U.S.-Russian nuclear security cooperation. The Global Initiative to Combat Nuclear Terrorism, co-chaired by the United States and Russia, has put Russia in the role of joint leader of a global effort, rather than only a recipient of assistance. To date, however, many aspects of a real partnership are not yet in place: Russia is still spending much less than needed on nuclear security at home, and refusing to contribute significantly to nuclear security in other countries. (The United States, for example, is paying 100 percent of the costs of shipping Soviet-origin HEU back to Russia, and then paying Russia to process it there.) Many U.S. approaches—such as fundamental decisions on what security standards teams working to improve security at Russian sites should be seeking to meet—are still decided with little Russian input. Many Russian sites still see themselves as recipients of U.S. assistance rather than full partners, remaining heavily dependent on a continuing flow of U.S. money for nuclear security and accounting. Whether this addiction can be broken in the next few years remains a critical unanswered question.

A genuine nuclear security partnership cannot be built in a political vacuum. The war in Georgia in August 2008 led to a sharp rise in U.S.-Russian hostility, and came on top of earlier disputes over Russia's treatment of its neighbors; Russia's approach to democracy and governance; political disputes in Georgia, Ukraine, Kosovo, and elsewhere; U.S. concerns over Russia's arms sales and nuclear cooperation with Iran; Russian concerns over NATO expansion and U.S. plans to deploy missile defenses in Europe; and more. While nuclear security cooperation has continued in spite of the new hostility—even after the war in Georgia—this political atmosphere is likely to make it far more difficult to build a strong and lasting partnership. Both the United States and Russia have routinely made decisions on these central issues in the U.S.-Russian relationship with only modest consideration of their potential impact on both sides' fundamental interest in co-

[171] For a discussion of how a partnership-based approach might differ from past approaches, see 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 8 July 2008). See also U.S. and Russian Committees on Strengthening U.S. and Russian Cooperative Nuclear Nonproliferation, U.S. National Academy of Sciences and Russian Academy of Sciences, *Strengthening U.S.-Russian Cooperation on Nuclear Nonproliferation: Recommendations for Action* (Washington, D.C.: National Academy Press, 2005; available at http://books.nap.edu/catalog/11302.html as of 18 June 2008).

operating to keep nuclear stockpiles out of terrorist hands.

Elsewhere in the world, the distance between the situation today and a real nuclear security partnership is even broader—yet such partnerships are needed wherever the most dangerous nuclear stockpiles exist.

Ensuring sustainability

If the United States and other donor countries spend billions helping to install upgraded nuclear security and accounting equipment in Russia and around the world, but much of the equipment is broken and unused five years after U.S. assistance comes to an end, the goal of lasting reductions in the risk of nuclear theft and terrorism will not have been achieved. Taking steps to ensure that countries put the resources, incentives, and organizations in place to ensure that that effective nuclear security and accounting will be sustained for the long haul is critical both to reducing the risk and to protecting the investments the United States and other donor countries have already made.

As discussed above, there has been significant progress on sustainability in Russia, though ultimate success remains uncertain. The U.S. and Russian governments have reached an agreement on sustainability principles, and U.S. and Russian experts are working to lay out sustainability plans for each site, in which U.S. funding will gradually decline and Russian funding will increase, until the systems are financed without continuing U.S. help. But to date, Russia still appears to be investing far less than is likely to be needed to sustain effective nuclear security and accounting over time, and its nuclear security and accounting regulations remain weak (giving nuclear managers only limited incentives to develop and maintain effective security and accounting measures).

Elsewhere in the world, less has been done to ensure that nuclear security improvements will be sustained, and the future remains highly uncertain. Any sustainability discussions that may have taken place with Pakistan remain confidential, but it is clear that the Pakistani government has both limited resources and a wide range of other priorities it is focused on at present, raising concerns over whether Pakistani investment will be adequate over the long haul. In China, as discussed above, many sites do not appear to have undertaken major nuclear security upgrades to date, but if it does do so, it seems likely such upgrades would be sustained, since they would be result of China's own investments rather than being funded by the United States or other donor countries. No nuclear security cooperation has yet gotten under way with India, so sustainability of upgrades provided is not an issue. When GTRI helps upgrade security at HEU-fueled research reactors, it generally provides funds to the IAEA to allow the IAEA to provide training and limited assistance in maintaining the installed systems. But this certainly does not cover the full cost to these sites of providing effective security (such as the cost of a well-trained and well-motivated armed guard force). In many countries where these reactors exist (especially the United States itself)[172] nuclear security

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[172] As discussed earlier, NRC-regulated research reactors are exempted from most of the security requirements that would otherwise apply to any site with HEU, simply because they are research reactors. See 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 28 September 2005).

regulations for these HEU-fueled reactors are weak, giving nuclear managers little incentive to keep extensive (and expensive) nuclear security measures in place and operational.

Strengthening security culture

As discussed above, building strong security cultures is also critical to the success of nuclear security improvement programs.

The literature on organizational culture makes clear that lasting cultural change is a very difficult thing to accomplish. 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[173]—which means that the first job is to convince senior nuclear managers of the importance of achieving strong security cultures in their organizations. This gets back to the central importance of perceptions of the threat: nuclear managers are not likely to make nuclear security a top organizational priority, and nuclear staff are not likely to spend their time following inconvenient security procedures, unless they believe that these security measures are genuinely needed to prevent a clear danger to their own country's security.

As the recent Air Force incidents (and the string of incidents over the years at Los Alamos) make 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;[174] 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.[175] Trying to improve security culture in other countries, whose national cultures U.S. officials may not understand well and where U.S. programs and preferences may 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.

As discussed above, the United States and Russia have established a joint security culture program, which includes development and pilot testing of approaches to assessing the state of security culture at particular facilities, training programs, security culture coordinators at 10 Russian nuclear sites, and drafting of a new

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

[174] 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."

[175] Steven Mufson, "After Breaches, Head of U.S. Nuclear Program Is Ousted," *Washington Post*, 5 January 2007 available at http://www.washingtonpost.com/wp-dyn/content/article/2007/01/04/AR2007010401813.html as of 11 November 2008.

Russian regulation on security culture.[176] Moreover, the technical upgrades that have been put in place themselves have an effect on security culture: when material is kept in a secure vault with detectors, alarms, and security cameras everywhere and men with guns guarding it, people think about the importance of security for that material in a different way than they do when it is stored in the equivalent of a high-school gym locker with a padlock. Nevertheless, in Russia as in the United States, there continue to be indicators of lack of belief in the threat and weak security culture.

Elsewhere, discussions and efforts to promote nuclear security culture have not been as extensive. Many nuclear managers and staff remain convinced that security threats are minimal and further measures are not required. While the IAEA has for years had an extensive program to help countries assess and improve nuclear safety culture (including both guidance documents and peer reviews), its first document on assessing and improving nuclear security culture has only just been published, after years of delay.[177] In addition to this guidance document, the IAEA has begun offering workshops focused on approaches to improving security culture. (The IAEA has also established a Security Series of documents, paralleling its Safety Series, but except for the single document on security culture, these largely focus on technical issues related to physical protection, detection of nuclear material, nuclear forensics, and the like.) The newly established World Institute of Nuclear Security (WINS) should provide a forum for exchanging best practices in strengthening security culture, potentially helping to strengthen security culture worldwide.[178]

Table 2.4 summarizes the progress to date and the distance yet to travel in putting in place the international policy frameworks necessary to achieve effective nuclear security worldwide.

Building U.S. Policy Frameworks: Steps Taken and Work Yet to Do

Beyond international initiatives, there are steps that must be taken within the United States to put in place policy frameworks that will support a robust effort to achieve effective nuclear security around the world. Other states with major stockpiles to secure or resources to help should take similar steps as well—and the United States should work to convince them to do so. Such action is particularly needed in Russia, which shares a special responsibility with the United States, as between them these two countries have more than 95 percent of the world's nuclear weapons and more than three-quarters of the world's stockpiles of weapons-usable nuclear material. This section assesses domestic efforts to: (a) put some in charge of efforts to prevent nuclear terrorism; (b) develop and implement a comprehensive and prioritized plan for securing nuclear stockpiles and preventing nuclear terrorism; (c) provide sufficient resources, matched to priorities; (d) overcome bureaucratic impediments; and (e) build a

[176] Interview with U.S. national laboratory expert, July 2008. See also the website of the Russian participants in the security culture program (in Russian), available at http://culture.mpca.ru as of 22 July 2008.

[177] International Atomic Energy Agency, *Nuclear Security Culture: Implementing Guide*, Security Series No. 7 (Vienna: IAEA, 2008), available at *www-pub.iaea.org/MTCD/publications/PDF/Pub1347_web.pdf* as of 30 October 2008.

[178] For a brief introduction to WINS, see "NTI in Action: World Institute for Nuclear Security (WINS)," available at http://www.nti.org/b_aboutnti/b7_WINS.html as of 30 October 2008, and documents available there. The WINS website, which so far has limited information posted, was available at http://www.wins.org as of 30 October 2008.

Table 2.4: Building International Policy Frameworks: Progress by Category of Effort

Category	Assessment
Building the sense of urgency and commitment worldwide	Some progress, but major obstacles till to overcome. Global Initiative to Combat Nuclear Terrorism and expanded dialogues with foreign intelligence agencies have helped heighten international awareness of the threat. Many nuclear officials and policymakers in key countries, however, continue to believe that it would be almost impossible for terrorists to get the material for a nuclear bomb or to make a bomb from it if they did get hold of it.
Creating a fast-paced global nuclear security campaign	Some progress, but important gaps remaining. The Global Initiative to Combat Nuclear Terrorism has highlighted the threat with many countries, but has focused more on issues such as law enforcement, radiation detection, and emergency response. The Global Partnership Against the Spread of Weapons and Materials of Mass Destruction has moved slowly and spent very little on upgrading security for nuclear stockpiles. Most countries with nuclear stockpiles not yet focused on rapidly improving the security for these stocks and helping other countries to do the same. WINS will help exchange nuclear security best practices, and may help focus attention on the threat.
Forging effective global nuclear security standards	Limited progress. Neither the amended physical protection convention nor the nuclear terrorism convention set standards for how secure nuclear stockpiles should be. UN Security Council Resolution 1540 legally obligates all states to provide "appropriate effective" security and accounting for nuclear stockpiles, but there is no agreed definition of what essential elements are needed to meet this requirement. Discussions of a revision to IAEA physical protection recommendations that might provide more specific standards are under way.
Building strong nuclear security partnerships	Some progress, more to be done. The Global Initiative to Combat Nuclear Terrorism, co-chaired by the United States and Russia, has put Russia in the role of joint leader of a global effort, rather than only recipient of assistance. Since the Bratislava summit, U.S.-Russian discussions have included more genuine exchanges of approaches and best practices. But souring U.S.-Russian relations in the aftermath of the conflict in Georgia may make new cooperative agreements and real partnership more difficult to achieve – though existing nuclear security cooperation has not been cut back. Russia is still under-investing in nuclear security at home (relying heavily on U.S. funding at many Russian sites), and refusing to invest in upgrading security or consolidating stockpiles elsewhere. U.S. decisions on issues such as Georgia, missile defenses in Europe, NATO expansion, and Kosovo are being taken with limited consideration of the potential impact on nuclear security cooperation. Efforts to begin building nuclear security partnerships with other countries are just beginning.
Achieving Sustainability	Significant progress in Russia, limited progress elsewhere. U.S. and Russian governments have reached accord on sustainability principles, are working to lay out sustainability plans for each site – but Russia still investing less than is likely to be needed. In other countries, there have been less extensive upgrades and less focus on putting in place the resources, organizations, and incentives needed to ensure that high levels of nuclear security are sustained.
Strengthening security culture	Some progress in Russia, limited progress elsewhere. U.S. and Russian governments have established a security culture pilot program at ten facilities in Russia, and developed a joint methodology for security culture assessment, but much more remains to be done. The IAEA's first document providing guidance on assessing and strengthening security culture has just been issued, after years of delay. Many nuclear managers and staff remain convinced that security threats are minimal and further measures are not required. WINS should provide a forum for exchanging best practices in strengthening security culture.

Source: Author's estimates.

sustainable coalition to support these efforts and ensure that they get the priority and resources they require.

Putting someone in charge

A crucial first step would be to put someone in overall charge of U.S. efforts to secure nuclear stockpiles and prevent nuclear terrorism. Today, there is literally no one in the U.S. government with full-time responsibility for leading all the disparate efforts to prevent nuclear terrorism. These efforts are splintered among dozens of programs in several cabinet departments, and the lines of responsibility do not come together in any one person short of the President. There is a very capable junior official on the National Security Council staff who helps coordinate most cooperative threat reduction programs in foreign countries, but that official has little power to set new priorities or shift agency budgets, little ability to get the president's ear, and no responsibility for the many other elements of national power, from intelligence and counter-terrorism to high-level diplomacy with states such as Russia and Pakistan.

There has been little progress in changing this situation, either in the Clinton years or the Bush years. In 1996, Congress passed legislation requiring the appointment of a senior official to be responsible for nonproliferation—legislation the Clinton administration largely ignored. In 2007, Congress passed more specific legislation mandating the creation of a new office in the White House with full-time responsibility for managing all of the nation's efforts to prevent the spread of nuclear, chemical, or biological weapons to additional states or terrorist groups. The Bush administration has so far refused to appoint anyone to this post.[179]

Developing and implementing a comprehensive, prioritized plan

After putting someone in charge of the overall effort, the next step would be to develop and implement a comprehensive, prioritized plan tying together all the disparate efforts to reduce the risk of nuclear terrorism, so that the greatest efforts could be focused on the areas that showed the greatest opportunities for risk reduction and gaps and overlaps in U.S. programs identified.

While prioritized plans have been developed for particular programs—such as the effort to secure nuclear stockpiles in Russia, or the effort to remove HEU from research reactors—there is as yet no comprehensive, prioritized plan that addresses all the steps that need to be taken to reduce the risk of nuclear theft and terrorism worldwide. While it has not been made public, the closest thing to such a plan that exists may be the initial draft of a "global nuclear detection architecture" produced by the Domestic Nuclear Detection Office (DNDO) of the Department of Homeland Security. Although this architecture focuses primarily on detection of already-stolen material, it also includes at least references to programs for preventing nuclear theft; all told, it covers 74 separate government programs. After reviewing the initial architecture, however, the Government Accountability Office (GAO) concluded that it largely identified pre-existing programs and their plans, and that DNDO "lacks an

[179] See, for example, Bryan Bender, "Bush Fails to Appoint a Nuclear Terror Czar," *Boston Globe*, 22 June 2008, available at http://www.boston.com/news/nation/washington/articles/2008/06/22/bush_fails_to_appoint_a_nuclear_terror_czar/ as of 11 November 2008.

overarching strategic plan to help guide how it will achieve a more comprehensive architecture." GAO recommended that the administration develop such a comprehensive plan, including specific designation of agency responsibilities, needed resources, and metrics of progress.[180]

In 2004, Congress passed legislation requiring the Secretary of Energy to submit a report detailing the sites around the world that posed the highest risks of nuclear theft, and a plan for removing the material from these sites or securing them, "including measurable milestones, metrics, and estimated costs for the implementation of the plan."[181] What they got in response were three prioritized lists from three of NNSA's programs —even within NNSA, the programs were unable to agree on a consolidated set of priorities, let alone doing so between NNSA and other agencies.[182]

One crucial first step toward a comprehensive plan is a comprehensive list of the nuclear stocks around the world that need to be secured. In response to the 2004 requirement, NNSA did compile lists from several programs into an overall list.[183] But this list still did not include many of the kinds of information that would be needed to establish priorities, such as estimates of the insider and outsider threats in the areas where these materials exist. In early 2006, President Bush signed a directive establishing the Nuclear Materials Information Program (NMIP), a "DOE-managed interagency program to develop an integrated system of information from all sources… concerning worldwide nuclear material holdings and their security status."[184] NMIP, managed by DOE's Office of Intelligence and Counterintelligence (DOE-IN), has compiled information on and assessed hundreds of high-priority nuclear sites, but is not yet complete—and will be continuously updated and expanded as needed.[185] In addition, the U.S. government and several other states have been working with the IAEA's Office of Nuclear Security to put together a list of more than 500 nuclear and radiological sites around the world that have already received some form of security upgrades, and some 500 more that may still require upgrades.[186]

In December 2007, as part of the omnibus appropriation, Congress passed a provision originally sponsored by Senators Barack Obama and Chuck Hagel, requiring the administration to submit a "comprehensive nuclear threat reduction and security plan" focused on "ensuring that all nuclear weapons and weapons-usable material at vulnerable sites are secure

[180] U.S. Congress, Government Accountability Office, *Nuclear Detection: Preliminary Observations on the Domestic Nuclear Detection Office's Efforts to Develop a Global Nuclear Detection Architecture,* GAO-08-999T (Washington, D.C.: 16 July 2008, available at http://www.gao.gov/new.items/d08999t.pdf as of 4 August 2008).

[181] Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005, Public Law 108-375, Section 3132.

[182] 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 an NNSA official, November 2005.

[183] Data provided by NNSA, October 2007.

[184] Quote is from memo from NNSA, October 2007.

[185] Interview with DOE-IN official, April 2008.

[186] Data provided by NNSA, October 2007.

by 2012 against the threats that terrorists have shown they can pose" and that this level of security would be sustained thereafter.[187] To date, however, there is no public indication that this requirement is leading to more than simply compiling pre-existing plans of various programs focused on nuclear security, which, even in combination and even if wholly successful, would not reach the comprehensive goal specified in the Obama-Hagel provision.

Providing sufficient resources, matched to priorities

After putting someone in charge and developing a plan of action, the next step is to make sure there are sufficient resources to implement the plan. Resources available for programs to improve security for nuclear stockpiles and attempt to interdict nuclear smuggling around the world have increased substantially since the 9/11 attacks. In most cases, these increases have been driven by Congress, with Congress typically appropriating more for several of these programs than was requested and the administration then going along with most of this congressional increase in the next year's request.[188] As described in detail in the next chapter, however, it is still the case that several programs could make faster progress with additional funds. And if other policies could break through the political and bureaucratic obstacles that limit cooperation in preventing nuclear terrorism, more money would be needed to implement an accelerated effort.

No consistent government-wide process is in place, however, to assign funds to the highest-priority efforts or to reassign funds as new opportunities arise. Resources for DOE's programs are considered within DOE and reviewed by one Office of Management and Budget (OMB) examiner, DOD's programs are considered with DOD and reviewed by another OMB examiner, and State's programs are reviewed within State and considered by another examiner in a different section of OMB. There has been no overall review of these programs since 2001, and that review largely ratified the efforts already in place.[189]

Overcoming bureaucratic impediments

For years, a wide range of bureaucratic obstacles in both the United States and recipient countries have slowed progress in nuclear security cooperation. Slow contracting and review procedures, repeated disputes over secrecy and access to sensitive sites, lack of flexibility, lack of high-level intervention to overcome obstacles that could not be resolved at lower levels, and more have slowed work, in some cases for months or years at a time.[190] Dedicated experts from sites and laboratories, along with officials in Washington, Moscow, and elsewhere, have struggled to overcome these obstacles, with some important successes—but there is more to be done.

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187 *Consolidated Appropriations Act of 2008,* Public Law 110-161, Section 699M.

188 See discussion in Anthony Wier and Matthew Bunn, *Funding for U.S. Efforts to Improve Controls over Nuclear Weapons, Materials, and Expertise Overseas: Recent Development and Trends* (Cambridge, Mass.: Project on Managing the Atom, Harvard University, 2007; available at http://www.nti.org/securingthebomb as of 9 June 2008).

189 For a useful discussion, see Cindy Williams and Gordon Adams, *Strengthening Statecraft and Security: Reforming U.S. Planning and Resource Allocation* (Cambridge, Mass.: MIT Security Studies Program, June 2008), pp. 45-56.

190 See, for example, "What are the Main Impediments to Action?" and "Warhead Security: The Saga of the Slow 'Quick Fix'," in Bunn and Wier, *Securing the Bomb: An Agenda for Action*, pp. 74-75, 52-53.

Congress took an important step in 2007 by passing legislation that eliminated the cumbersome certification requirements for Nunn-Lugar programs, which had taken up a substantial amount of officials' time each year, and had, on some occasions, stopped programs abruptly when certifications were not made on time. Congress has also consolidated some reporting requirements. But many frustrating obstacles remain. One key job for a senior White House leader for these programs must be to identify and resolve the most important and resolvable impediments to accelerated progress in reducing the risk.[191]

Building a sustainable coalition of support

To sustain any costly and difficult effort over the long haul requires a broad coalition of support, particularly in the U.S. Congress. Significant progress has been made in building support for these efforts over the years, but here, too, there is more to be done. There is broad support for most nuclear security programs in Congress and from both the Democratic and Republican presidential candidates in the United States. Virtually every year since 9/11, Congress has appropriated either 100 percent or more of the budget request for the most important nuclear security programs. But there are still very few members of Congress who get directly involved in these efforts, or propose new initiatives. Few lobbyists work on strengthening or accelerating these programs, as there are no large firms that get more than a few percent of their revenue from these efforts. While there is broad public support for cooperation to keep nuclear weapons and materials out of terrorist hands, that support is unfocused and results in little active pressure for expanded and accelerated efforts.

Beyond Nuclear Security

Improving security for nuclear stockpiles, and hence reducing the likelihood that a nuclear weapon or the materials to make one could be stolen, is the single policy step that can do the most to reduce the risk of nuclear terrorism. 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. As Robert Nesbit, co-chair of a Defense Science Board task force on strategies to reduce the risk of terrorist attacks with nuclear, chemical, or biological weapons told Congress in mid-2008, if a theft or transfer to terrorists ever occurs, "we are in big trouble," as "it would be very difficult to detect in transit, stop, and secure the device prior to detonation."[192]

Nonetheless, because efforts to lock down nuclear stockpiles around the world are not likely to be 100 percent successful—and because some undetected thefts of nuclear material may already have occurred—the world should make some investment in other lines of defense. The questions are how much effort and money to invest, and where best to invest it, given the immense challenges the problem poses. Here, I will offer only brief assessments of progress in several areas of effort.

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[191] For a discussion focused on bureaucratic issues within the United States and how they might be resolved, based on extensive interviews with program managers and contractors, see Brian D. Finlay and Elizabeth Turpen, *25 Steps to Prevent Nuclear Terrorism: A Guide for Policymakers* (Washington, D.C.: Henry L. Stimson Center, January 2007).

[192] Robert F. Nesbit, testimony in U.S. Senate, Committee on Homeland Security and Governmental Affairs, "The Global Nuclear Detection Architecture: Are We Building Domestic Defenses That Will Make the Nation Safer?", 16 July 2008 available at http://hsgac.senate.gov/public/_files/071608Nesbit.pdf of 11 November 2008.

Table 2.5: Building Domestic Policy Frameworks: Progress by Category of Effort

Category	Assessment
Putting someone in charge	Little progress. Congress passed, and President Bush signed into law, legislation requiring the appointment of a full-time White House official to lead efforts to prevent nuclear, chemical, and biological proliferation and terrorism, but no such official has been appointed.
Developing and implementing a comprehensive, prioritized plan	Little progress. Congress passed, and President Bush signed into law, legislation requiring the development of a comprehensive plan to ensure that all nuclear weapons and all stocks of plutonium and HEU worldwide were sustainably secured against demonstrated terrorist and criminal capabilities by 2012. To date, however, there is no public indication that the administration will do more than staple together the pre-existing plans of various programs focused on nuclear security, which, even in combination and even if wholly successful, would not cover all stocks of plutonium and HEU worldwide. The Nuclear Materials Information Program is working to collect and analyze the data on nuclear materials and their security worldwide that would provide the basis for such a plan.
Providing sufficient resources, matched to priorities	Significant progress, but more to be done. Spending on programs to reduce the risk of nuclear terrorism has increased substantially, and money is now a less important constraint than cooperation for most programs. No consistent process in place, however, to assign funds to the highest-priority efforts or to reassign funds as new opportunities arise. Some programs could accelerate progress now if provided additional funds. If other policies could break through the political and bureaucratic obstacles to cooperation, more money would be needed to implement an accelerated program.
Overcoming bureaucratic impediments	Significant progress, but more to be done. Congress has removed the threat-reduction certification requirements that slowed progress, and has consolidated some reporting requirements. Cumbersome contracting procedures, difficulties between NNSA and DOD and their labs and contractors, and other issues continue to be issues.
Building a sustainable coalition of support	Significant progress, but more to be done. Broad support for most nuclear security programs on Capitol Hill and from both presidential candidates. But in many cases, pro-active initiatives still depend on a tiny handful of members of Congress. Little active support from private industry, as there are no large firms that get more than a few percent of their revenue from these programs. Broad public support is unfocused and results in little active pressure for expanded and accelerated efforts.

Source: Author's estimates.

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.[193]

[193] 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).

Here, as discussed in the previous chapter, there is a mixed picture. On the one hand, the disruption of al-Qaeda's old centrally controlled operation, the removal of the sanctuary in Taliban-controlled Afghanistan, and the capture of a significant number of high-level operatives surely reduced al-Qaeda's ability to put together an operation as complex as getting nuclear material and building a nuclear bomb. The extent of U.S. and other intelligence and counter-terrorism efforts focused on these highest-capability terrorist groups has increased substantially since the 9/11 attacks, and that is presumably also making it more difficult for terrorists to carry large and complex operations through to conclusion. On the other hand, al-Qaeda's growing strength in the sanctuary of the tribal areas of Pakistan presumably means that the risk is growing again; the surge in terrorist strength in Pakistan presumably increases the risk that material or expertise there would find its way into terrorist hands; and the dramatic increase in anti-American hatred since the beginning of the Iraq war in 2003 has increased the risk that terrorists would succeed in finding recruits with access to nuclear materials or expertise, and in raising the money for such an expensive operation.

On balance, the potential for al-Qaeda or other terrorist groups to mount an attack with a nuclear bomb is almost certainly lower today than it was before 9/11—but over the past year or more, it appears to have been growing, as the group has become ever more able to plan and operate in the Pakistan sanctuaries.[194] U.S. efforts to counter nuclear-capable terrorists are evolving and adapting, but so are the terrorist groups they are trying to counter—and it is not yet clear who is winning that race.

Interdict: Countering the Nuclear Black Market

Clearly, it is also important to stop smuggling of already stolen nuclear material—from the theft site to where it might be sold to a buyer, from there to a safe haven where a bomb might be constructed, and from there to targets, in the United States or elsewhere. But stopping smuggling of material that can fit in a suitcase, and whose radiation is weak and difficult to detect (especially in the case of HEU metal, the easiest material for terrorists to use to make a bomb), is an extraordinary challenge.

To meet this challenge, it is crucial to focus effort where success is most likely, given an intelligent adversary. Only one of the real seizures of stolen plutonium or HEU involved radiation detectors at borders;[195] the rest were mostly either sting operations or cases where one of the conspirators or one of the people they tried to sell their stolen material to informed on the plot. As a first step, the United States and other concerned coun-

[194] 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).

[195] This was the 2003 HEU seizure in Georgia, which U.S. officials attribute to U.S.-supplied radiation detectors. This reported detection is somewhat surprising, as the detectors in place at that site at the time were older-generation systems that would be expected to have little capability to detect small amounts of HEU. One unconfirmed report suggests that the Georgian agents who had been tailing the smuggler warned the border post before his arrival—so the detection may have had as much to do with intelligence as with detection technology. See Michael Bronner, "100 Grams (And Counting): Notes From the Nuclear Underworld" (Cambridge, Mass.: Project on Managing the Atom, Harvard University, June 2008, available at http://belfercenter.ksg.harvard.edu/files/Bronner percent20Booklet percent20Final.pdf as of 30 July 2008).

tries should do more to build on this past success, encouraging such informing with well-publicized anonymous tip hotlines or websites, rewards for credible information, and the like. There is no public evidence that much has been done toward this end to date.

Second, intelligence and police agencies need to apply more resources to understanding the incentives that lead to nuclear theft and smuggling; the networks, routes, and tactics being used; and the identities and approaches of buyers searching for black-market nuclear material.[196] Understanding and responding to nuclear smuggling will require a drastic increase in international police and intelligence cooperation; since the smuggling networks are international, the response must be as well. U.S. intelligence agencies have substantially increased the resources focused on tracking and interdicting nuclear smuggling since 9/11, and U.S. officials report that such cooperation is increasing—but there is much more to be done.[197] The Global Initiative to Combat Nuclear Terrorism provides an important new forum for bringing law enforcement officials together to discuss these issues—and indeed, one of the initiative's first major events was a large law enforcement conference in Florida in 2007.

Third, more sting operations can also provide a critical means for corralling material that has already been stolen—but must be carefully designed to avoid creating a perception of market demand for stolen material that could provoke new thefts, and to avoid providing useful information to terrorists and blackmarketeers on law relevant enforcement and surveillance routines in this area. Stings, scams, and other intelligence operations can shed light on the participants in the shadowy nuclear black market and make one of the big obstacles to terrorists getting stolen nuclear material even bigger, by making it harder for either the seller or the buyer of nuclear material to be sure the people they are dealing with are not government agents.[198] Such sting operations should be widely publicized, to further heighten this uncertainty among illicit nuclear traders. To date, however, such sting operations are in general being carried out in secret by police and intelligence organizations, so it is difficult to judge from publicly available information what progress they are making. The most recent significant HEU seizure, however, in Georgia in 2006, was the result of a sting carried out by Georgian intelligence agencies, building on tips from informers in South Ossetian organized crime groups—though the sting almost failed when the government agents showed up for the "buy" with no cash, and the suspects fled.[199] Building such networks of informers, especially among smugglers of various types of contraband and the semi-feudal tribal chieftains who control some of the world's most dangerous borders, is

[196] For a discussion emphasizing such an intelligence-based approach, see 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 18 June 2008).

[197] Interview with DOE intelligence official, December 2007. See also testimony by Rolf Mowatt-Larssen, director, DOE Office of Intelligence and Counterintelligence, U.S. Senate, Committee on Homeland Security and Governmental Affairs, 2 April 2008 available at http://hsgac.senate.gov/public/_files/040208MowattLarssen.pdf as of 11 November 2008.

[198] Matthew Bunn, "Designing a Multi-Layered Defense against Nuclear Terror," paper presented at The Homeland Security Advisory Council Task Force on Weapons of Mass Effect, Washington, D.C., 13 June 2005 (available at http://belfercenter.ksg.harvard.edu/publication/17189/designing_a_multilayered_defense_against_nuclear_terror.html as of 8 July 2008).

[199] Bronner, "100 Grams (And Counting)".

likely also to be a critical element in the fight against nuclear smuggling—though again one whose progress is difficult to judge from publicly available information.

Fourth, experience suggests that it would be valuable for each potential source state and likely transit state to have designated units of their police or intelligence forces focused on nuclear smuggling, with the expertise and resources to probe the issue in-depth. The 2006 Georgian seizure was reportedly carried out by such a specialized unit.[200] Some of these states have taken action to put such units in place, but others have not. U.S. programs such as DOD's International Counterproliferation Program have provided training for hundreds of law enforcement and customs personnel from key countries. The IAEA Office of Nuclear Security also helps assess countries' enforcement capabilities and provides training. But how much of the need for units with relevant expertise focused on nuclear smuggling has been filled remains unclear. Helping to establish such units could be an important role for the State Department's Nuclear Smuggling Outreach Initiative in the future. Training for law enforcement and border control personnel should include not only issues related to nuclear material, but also at least basic information that will help them recognize and interdict equipment that might be useful in making a crude nuclear bomb (such as appropriate furnaces and crucibles for casting uranium or plutonium metal, to take just one example). NNSA has been providing such equipment-focused training in a number of countries, as part of its program to strengthen international export controls, but this effort could be significantly expanded.

[200] Bronner, "100 Grams (And Counting)".

Fifth, to deter nuclear thieves and smugglers, it is important not only to increase the chance that they will be caught, but also to ensure that they will be severely punished if they are caught. As a result of treaties such as the nuclear terrorism convention and the amendment to the physical protection convention (which require parties to make nuclear theft and smuggling crimes), along with the legal requirements of UN Security Council Resolution 1540 (which requires states to put in place laws making it a crime to help or attempt to help any non-state actor get nuclear, chemical, or biological weapons), a number of states have put in place new criminal laws on nuclear theft and smuggling in recent years.[201] Here, too, the IAEA Office of Nuclear Security helps assess countries' legal infrastructure and helps them put appropriate laws in place. But a substantial number of countries still 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. Under Article 189 of Russian criminal law, to take one particularly important example, the maximum punishment for illegal export of items that could be used to make a nuclear weapon is only three years in prison—though other articles relating to treason and related crimes might be used to stiffen the penalty in a particular case.[202]

[201] The Security Council's 1540 Committee has established an on-line database of relevant national legislation, though most of it is only available in the original national languages. The database was available at http://www.un.org/sc/1540/legisdatabase.shtml as of 30 July 2008.

[202] Russian Federation, Report of the Russian Federation on the Implementation of Security Council Resolution 1540 (2004) (New York: United Nations, 26 October 2004), available at http://daccessdds.un.org/doc/UNDOC/GEN/N04/589/76/PDF/N0458976.pdf as of 12 November 2008.

Making that nuclear smugglers see a high chance of being prosecuted and convicted is just as important as making sure that penalties for conviction are stiff. In the past, many nuclear smugglers have spent little if any time in jail, which must change if future nuclear smugglers are to be deterred. Today, for example, many of the partipants in the A.Q. Khan nuclear technology network are still free men. The world is still a long way away from a situation in which all relevant states have laws in place and commitments to prosecution that convince potential participants in nuclear plots that participating would carry with it a high chance of suffering a penalty comparable to the penalties for treason or murder.

Current efforts to put in place radiation detection at key border crossings around the world (and to improve nuclear detection within the United States) may also reduce the risk somewhat, forcing smugglers to pursue more difficult and chancier routes. But the utility of installing large, highly visible radiation detectors at ports and border crossings will inevitably be limited in coping with sophisticated adversaries (such as smugglers from groups with the expertise needed to make a nuclear bomb). Such smugglers may simply use one of the many other possible routes where such detectors are not present; may carry their material in the form of shielded HEU metal, which the detectors now being installed could not detect; or may use bribery or other techniques—which they might test repeatedly before the real shipment—to get through the detectors without being stopped. As a result, such highly visible detectors at official points of entry probably only reduce risk significantly in the case of unsophisticated adversaries such as the befuddled small-time criminals responsible for most of the HEU and plutonium smuggling cases of the 1990s, who knew little about radiation detection or sophisticated smuggling approaches, and often carried their material with little or no shielding, in forms such as oxide powder (which are easier to detect than HEU metal, because of neutrons released by reactions between the alpha particles emitted by the uranium and the oxygen atoms in the powder).[203] The key question—still unresolved—is how much it is worth investing in detection systems that more sophisticated adversaries can readily bypass.[204]

Currently, the U.S. government is investing hundreds of millions of dollars a year in such detectors. 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. By December 2007, DHS had met the Congressionally-imposed mandate to carry out scanning for all cargo containers at the 22 largest U.S. ports, representing 98 percent of the containers being shipped to the United States. In addition, DHS reports that it is now scanning 100 percent of the truck cargo arriving in the United States from Mexico and 91 percent of the truck cargo entering from Canada, for an average of 96 percent

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[203] For a useful discussion of the greater ease of detecting oxides, see Michael Levi, *On Nuclear Terrorism* (Cambridge, Mass.: Harvard University Press, 2007), pp. 83-85.

[204] 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 30 July 2008).

of all containerized cargo entering the United States.[205]

In 2007, Congress went further, and passed legislation requiring that, by 2012, 100 percent of the shipping containers entering the United States must go through a radiation scan before they arrive at the U.S. borders (since otherwise a hidden bomb might be detonated in a U.S. port before the container was scanned).[206] Unfortunately, such requirements for 100 percent 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 do not provide risk reduction that justifies the costs and inconveniences they impose. Meeting this U.S.-imposed mandate would require countries all over the world to make major investments in installing and operating radiation scanning systems. The legislation includes an option to waive the requirement if several specified conditions apply, and it appears likely that while the United States will push to get as many containers scanned abroad as possible, the requirement will be repeatedly waived.

NNSA's "Second Line of Defense" program is now playing the leading role in helping other countries deploy such radiation detectors, to meet this requirement and more broadly, to provide radiation detection capability throughout the global system for shipping cargo containers and at other international crossing points around the world that it has identified as priorities. 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.[207] (The 75 megaports to be covered under current plans are far fewer than the total number of ports shipping containers to the United States, all of which would have to have such scanners or send their U.S.-bound cargo through facilities that did to meet the Congressional requirement.) 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.[208] By the end of fiscal year (FY) 2007, such detectors were installed and operating at 162 of these border crossings—the majority of which were in Russia—and 12 megaports.[209] While this leaves the majority of the planned work yet to be done, Second Line of Defense has sought to take a prioritized approach, focusing first on those facilities judged to be the highest risks (and where it proved to be possible to negotiate agreements to install such equipment).

In addition, both DNDO and U.S.-funded programs overseas are working to at least begin to address the myriad pathways into the United States or across other borders that are between official points of entry. In the U.S. case, there are hun-

[205] Chuck Gallaway and Mark Mullen, DNDO, testimony in U.S. Senate, "The Global Nuclear Detection Architecture: Are We Building Domestic Defenses That Will Make the Nation Safer?," Committee on Homeland Security and Governmental Affairs, 16 July 2008 available at http://hsgac.senate.gov/public/_files/071608GallawayMullen.pdf as of 11 November 2008.

[206] *Implementing Recommendations of the 9/11 Commission Act of 2007*, Public Law 110-53, Section 1701.

[207] U.S. Department of Energy, *FY 2009 NNSA Budget Request*, p. 497.

[208] Department of Energy, "All of Russia's Border Crossings to be Outfitted with Proliferation Prevention Equipment," (1 June 2007; available at http://nnsa.energy.gov/news/1118.htm as of 30 July 2008); and Carl Giacomo, "U.S., Russia Agree on Nuclear Detection Plan," *Washington Post*, 1 June 2007. In its release, DOE reports that it is working to install detectors at some 350 border crossings in Russia (confirmed in data provided by NNSA, May 2008).

[209] U.S. Department of Energy, *FY 2009 NNSA Budget Request*, p. 497.

dreds of kilometers of unmarked forest between the United States and Canada and thousands of fishing boats which return from the open ocean each day and could easily have loaded something into their cargo holds while at sea. This vulnerability will be extraordinarily difficult to address. In these cases, radiation detection is not likely to be central to the answer: it is likely to be easier to catch the smugglers than to detect their nuclear materials. The many DHS programs to tighten control over the U.S. borders are likely to be important in this respect. In addition, DNDO has equipped all Coast Guard boarding teams with simple radiation detection equipment to contribute to searches of boats and ships that are boarded; is testing equipment for maritime radiation detection at several sites on the West Coast; is beginning to carry out scans of people on trans-oceanic non-commercial planes (known as "general aviation") arriving in the United States; is studying options for equipping border patrol agents in the areas between official points of entry with radiation detection equipment; and is completing deployment of radiation detectors around New York City in a pilot "Secure the Cities" initiative.[210] How much any of these efforts can reduce the risk, however, remains an open question.

U.S.-funded programs are sponsoring similar efforts in several countries abroad. Programs sponsored by both DOD and State have provided equipment and training to help countries patrol land and water areas between official entry and exit points—ranging from trucks and fast patrol boats to hand-held radiation detectors. NNSA's Second Line of Defense program is beginning to provide mobile radiation detectors to selected countries, which may be less obvious and easy for adversaries to avoid. But these efforts have only addressed a small part of the difficulty of detecting smuggling between official points of entry.

[210] Gallaway and Mullen testimony.

Moreover, some of the highest-priority borders around the world are simply not likely to be addressed effectively any time soon. To date, China does not appear to have deployed radiation detection equipment along its border with North Korea. There is no prospect that there will be effective radiation detection along with Pakistan-Afghanistan border for years to come. Cross-border routes in the Central Asian republics of the former Soviet Union have been used for smuggling a wide range of contraband since the age of the Silk Road. Border control coupled with radiation detection will always remain a very partial and leaky layer of defense in the struggle against nuclear terrorism.

Prevent and Deter: Reducing the Risk of Nuclear Transfers to Terrorists by States

As discussed in Chapter 1, 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.[211] 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 risk through a combination of deterrence, disarmament, and efforts to make such transfers more difficult to carry out.

[211] 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."

The United States has made progress in enunciating and clarifying a deterrent threat that states that knowingly transferred nuclear weapons or the materials to make them to terrorists would be "held to account," in President Bush's words—though the credibility of the deterrent threat may have been weakened by President Bush's remark that if North Korea took such action, the North Korean leader would be held to account "just like he's being held to account now for having run a test," suggesting that the response might be equally mild.[212] National Security Advisor Steven Hadley clarified the threat in early 2008, saying that "the United States has made clear for many years that it reserves the right to respond with overwhelming force to the use of weapons of mass destruction against the United States, our people, our forces and our friends and allies. Additionally, the United States will hold any state, terrorist group, or other non-state actor fully accountable for supporting or enabling terrorist efforts to obtain or use weapons of mass destruction, whether by facilitating, financing, or providing expertise or safe haven for such efforts."[213] The quick U.S. overthrow of the Taliban regime in Afghanistan after the 9/11 attacks presumably adds credibility to these statements. At the same time, however, such threats must be handled with extreme care, to avoid undermining the credibility of assurances to states of concern that cooperation in reducing nuclear dangers will be rewarded, and to keep from scaring states away from cooperation the United States may desperately need in the aftermath of an attack (for example cooperation in identifying sites that may have had unexplained losses of nuclear material in the years before the event, and the characteristics of the missing material).

Both for this deterrence purpose, and even more for helping to find and fix the source of any leakage of HEU or plutonium, it is important to develop the best practicable capability to identify where nuclear material came from (both for seized nuclear material and after a detonation if prevention efforts fail). Nuclear forensics—examining the isotopic and other characteristics of nuclear material to try to match it to possible sources—can contribute an important piece to other intelligence and police information, though there is no absolute "fingerprint" or "DNA match" for nuclear material. Nuclear forensics is more likely to be able to rule out possible sources of material than it is to be able to prove, on its own, that nuclear material came from one particular source. The Bush administration and Congress have acted to beef up U.S. nuclear forensics efforts, increasing the budget and establishing a national center for nuclear forensics under the Department of Homeland Security. The increased budget has largely not made it to the national laboratories, however, where most of the experienced U.S. experts in the topic reside; one U.S. laboratory recently had to reduce its nuclear forensics staff because of budget cuts.[214]

The picture is more mixed with respect to capping or rolling back the nuclear programs of states such as North Korea and

[212] For a pointed assessment of the weakness of this formulation, see Graham T. Allison, "Deterring Kim Jong-Il," *Washington Post,* 27 October 2006 available at http://www.washingtonpost.com/wp-dyn/content/article/2006/10/26/AR2006102601254.html as of 11 November 2008.

[213] Stephen Hadley, remarks to the Center for International Security and Cooperation, 8 February 2008, available at http://www.whitehouse.gov/news/releases/2008/02/20080211-6.html as of 31 July 2008.

[214] For a useful summary of nuclear forensics, see Nuclear Forensics Working Group (Michael May, chair), *Nuclear Forensics: Role, State of the Art, Program Needs* (Washington, DC: American Physical Society and American Association for the Advancement of Science, February 2008).

Iran. After years of refusing to engage with North Korea—with the result that North Korea withdrew from the Nonproliferation Treaty, kicked out international inspectors, reprocessed its plutonium to turn it into nuclear weapons, restarted plutonium production, and tested a nuclear bomb—the Bush administration finally decided to engage seriously, and the six-party talks have now achieved a renewed freeze on North Korean plutonium production and the disablement of the Yongbyon reactor, reprocessing plant, and fuel fabrication facility. Capping North Korea's plutonium stock at a low level (some 30 kilograms, if North Korea's declaration is correct) substantially reduces the risk that North Korean leaders would decide to sell some of this plutonium to others, or that key officials with access to the material might conclude that they could sell some of it off without detection. More in-depth engagement and more substantial incentives are likely to be needed, however, if there is to be any realistic chance of convincing North Korea that it is in its national interest to give up the weapons and plutonium it already has.

With respect to Iran, by contrast, as of October 2008 there had been essentially no progress in capping Iran's enrichment program, which offers the potential for rapid production of nuclear weapons material should Iran choose to do so in the future. Iran's enrichment program has grown from zero operating centrifuges to some 4,000 during the period when the Bush administration has been refusing to engage; Iran has significantly improved the performance of these centrifuges and is building up a stockpile of LEU that could rapidly be enriched to HEU. While the 2007 U.S. National Intelligence Estimate concluded that activities explicitly focused on weaponization had ended in late 2003, weaponization typically represents far less of the work of a nuclear weapons program than producing material does, and Iran appears to be well along in establishing the capability to produce HEU if and when it chooses to do so. Recent IAEA reports suggesting that Iran's past activities have included, among other things, testing of hemispheres of explosives with extremely precise timing—required for an implosion-type bomb, but for essentially nothing else—are particularly troubling. The Bush administration's belated decision to send a senior official to participate in talks with Iran over the most recent incentives package does not appear to have led to any progress, and there is little sign that Iran is ready to agree to cap or roll back its enrichment program. This may not be a surprise, given the Bush administration's bellicose approach up to this point. The incentives package as now structured in essence calls on Iran to stop all enrichment activity in return for discussions of a wide range of possible incentives, but no guarantees it will get any of them—in stark contrast to the "action for action, words for words" formulation that has proven successful with North Korea. Nor does it include any promise of a U.S. security assurance, even at the end of a long road during which other issues would be resolved—again in sharp contrast to the more successful approach taken with North Korea.

Ultimately, if there is to be hope for a compromise that will limit the risks of Iran's program to U.S. security, the United States will have to engage directly, working with other leading governments to gain international agreement on packages of carrots and sticks that are large and credible enough to convince Iran that it is in its interests to verifiably abandon its 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.[215]) For 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.[216]

Progress on the very difficult task of making it more difficult and risky for such states to transfer nuclear weapons or weapons-usable nuclear materials beyond their borders has been real but modest. The Proliferation Security Initiative (PSI) may modestly complicate such transfers by sea and air, but it is likely to be far more effective in dealing with transfers of large, detectable objects such as ballistic missiles or equipment for hundreds of centrifuges than it is in stopping transfers of material that would fit in a suitcase. As noted above, there do not yet appear to be radiation detection capabilities in place on China's border with North Korea. Much the same can be said of Iran's borders with states such as Iraq, Afghanistan, Pakistan, and Turkmenistan.

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.[217] 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 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.

Most other countries do not have similar capabilities in place, though a number of key countries (including Russia) do have teams trained to respond to nuclear emergencies in somewhat similar ways. Emergency response—including a broad range of emergencies, from theft of nuclear material or radioactive sources to sabotage of a nuclear reactor to detonation of a nuclear bomb—has been an important focus of U.S.-Russian discussions in recent years, and of the Global Initiative to

[215] 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).

[216] See, for example, Ray Takeyh, "Take Threats Off the Table Before Sitting With Iran," *Boston Globe*, 3 May 2007.

[217] 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?"

Combat Nuclear Terrorism. There is still a need, however, to put in place a better international rapid-response capability, 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.

Impede: Preventing Terrorist Recruitment of Nuclear Personnel

Al-Qaeda has repeatedly attempted to recruit personnel with the expertise to help them build a nuclear bomb. A wide range of steps should be taken to prevent such recruitment, from providing alternative employment for key experts to countering the anti-American hatred that can contribute to such recruitment efforts. Progress in these areas has been mixed at best.

The most prominent U.S. efforts in this area have been programs to provide alternative employment for Russian nuclear scientists (as well as chemical, biological, and missile experts). 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.[218] 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.[219] 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.[220] In short, despite the economic improvements in Russia, there is clearly still a case for continuing with efforts to engage personnel with poten-

[218] 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.

[219] "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.

[220] Surveys have found that foreign financing for civilian work reduces scientists' reported willingness to cooperate 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).

tially 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 nuclear bomb, but nuclear workers or guards who might help thieves steal the essential ingredients of a bomb.[221]

Several U.S.-funded programs, including NNSA's Global Initiatives for Proliferation Prevention (GIPP), the State Department's International Science and Technology Centers (ISTC), and the Civilian Research and Development Foundation (CRDF) provide support for civilian R&D projects for former nuclear weapons scientists, and, in some cases, for establishing sustainable long-term employment that no longer depends on foreign assistance. The short-term financial support and integration into the Western world of science that these programs offered probably played a crucial role in reducing proliferation risks amid the financial desperation at many nuclear facilities in Russia in the 1990s. NNSA, for example, estimates that by the end of FY 2007, 12,100 former weapons scientists were either working on GIPP grants or employed at firms created as a result of GIPP's efforts; of those, 4,400 were in long-term private sector jobs created with GIPP's help.[222] The Government Accountability Office, however, has pointed out that a large fraction of the people employed in these private-sector firms are not, in fact, former weapons scientists.[223] (It is hard to think of a new business in the United States or elsewhere that has former weapons scientists for 100 percent, or even 80 percent, of its employees.)

While these efforts have been reformed in recent years to focus more on transitioning participants to sustainable self-support, and to focus on institutes judged to be the highest priorities, there has been little change in more fundamental approaches. For a terrorist group, a physicist skilled in modeling the most advanced weapons designs—the kind of person who has often been the focus of these programs in the past—may be much less interesting than a machinist experienced in making bomb parts from HEU metal, or a guard in a position to let thieves into a building undetected. Experts who are no longer employed by weapons institutes, but whose pensions may be inadequate or whose private ventures may have failed, could pose particularly high risks, but they are not addressed by current programs focused on redirecting weapons expertise. Addressing all of these high-risk categories is likely to require different approaches and working with host governments to convince them to take most of the needed actions themselves.[224]

Measures beyond simply stabilizing employment are also important. While the United States has worked with Russia to strengthen personnel reliability programs for individuals with access to nuclear weapons and materials, for example,

[221] 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).

[222] U.S. Department of Energy, *FY 2009 NNSA Budget Request*, p. 481.

[223] See U.S. Government Accountability Office, *Nuclear Nonproliferation: DOE's Program to Assist Weapons Scientists in Russia and Other Countries Needs to be Reassessed* (Washington, D.C.: December 2007).

[224] 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.

the world is largely relying on whatever measures Russia takes itself to control classified nuclear weapons information, monitor contacts and behavior of individuals with key nuclear secrets, and the like. Similarly, the world is largely relying on whatever measures Pakistan has taken itself to control its nuclear weapon scientists and engineers and prevent either another A.Q. Khan black-market network, or other efforts to assist al-Qaeda's nuclear activities, such as were apparently carried out by Pakistani nuclear scientists in the group Ummah Tameer-e-Nau (UTN).[225] There is no publicly available information concerning the degree to which U.S. intelligence or other agencies are attempting to track or prevent recruitment at key sites, such as physics and nuclear engineering departments in countries with substantial Islamic extremist communities.

While U.S. National Security Advisor Stephen Hadley has emphasized the importance of "encouraging debate about the moral legitimacy of using weapons of mass destruction" in preventing nuclear terrorism, there is little public evidence that the United States has made much effort to do so—or would be considered a legitimate voice on this subject in the Islamic world. Nonetheless, as discussed in Chapter 1, even among violent Islamic extremists, a spirited debate has broken out over the moral legitimacy of the slaughter of innocents—provoked in part by one of the founders of al-Qaeda, who is now arguing strongly against violence as a tactic in all but very rare situations.[226] The spreading revulsion against such violence—and particularly the massive, indiscriminate slaughter that would be caused by a nuclear bomb—may well make it significantly more difficult for al-Qaeda to recruit nuclear experts for such a mission.

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. (At the same time, however, 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.) In this area, progress has been uneven.

Reducing nuclear weapon stockpiles. The United States and Russia, which between them possess over 95 percent of the world's nuclear weapons, have each dismantled thousands of nuclear weapons, and some level of dismantlement appears to be ongoing in both countries. Unfortunately, however, neither country has published current information concerning how many weapons it has dismantled, current dismantlement rates, or future dismantlement plans. Both countries appear to plan to retain thousands of nuclear weapons, including operational strategic weapons, tactical weapons, and weapons in reserve. Britain and France have announced reductions in their much smaller nuclear weapons stockpiles. Other states with nuclear weapons have not announced reductions.

[225] See, for example, Albright and Higgins, "Pakistani Nuclear Scientists: How Much Nuclear Assistance to Al-Qaeda?" Additional details are reported in Tenet, *At the Center of the Storm*, pp. 256-279.

[226] See Lawrence Wright, "The Rebellion Within," *The New Yorker*, 2 June 2008, pp. 37-53.

Reducing HEU stockpiles. The United States and Russia also possess over 95 percent of the world's HEU. Both have declared portions of their HEU stockpiles as excess to their military needs, and have begun reducing those excess stocks by blending them to low-enriched uranium (LEU). The HEU Purchase Agreement, under which Russia agreed to blend 500 tons of weapons HEU to LEU for purchase by the United States, is now more than half complete, with 337 tons of HEU having been blended and delivered as LEU by 30 June 2008.[227] This arrangement expires in 2013, at which time Russia will still have hundreds of tons of HEU, and no agreement has been reached for large-scale additional blending. Ten additional tons of HEU have been blended to LEU as part of NNSA's Material Consolidation and Conversion effort,[228] and a few tens of tons may also have been blended down for other commercial deals (such as the fabrication of fuel for European reactors at Elektrostal) or blended to LEU after being recovered from reprocessing HEU naval, icebreaker, plutonium production, or isotope production reactor fuel.[229] Similarly, by the end of FY 2008, the United States had shipped 117 metric tons of HEU for downblending, of 217 tons scheduled for blending or disposal.[230] Currently, however, the United States plans to retain enough HEU to support some 10,000 nuclear weapons, and Russia apparently plans to retain a far larger stock.[231]

Reducing plutonium stockpiles. World stockpiles of plutonium separated from spent fuel are more widespread. Roughly 250 tons of this material is in military stockpiles (more than 90 percent of which is in the United States and Russia), while roughly another 250 tons is in civilian stockpiles; the civilian stock is growing, and by the end of 2007 was likely larger than the amount of plutonium in all the world's weapon stockpiles combined.[232] The United States and Russia each declared quantities in the range of 50 tons of plutonium to be excess to their military needs in the 1990s, and signed an agreement in 2000 calling for disposition of 34 tons of weapons-grade plutonium on each side. In September 2007, the United States declared another 9 tons of plutonium excess, bringing its total to 61.5 tons (though some of that excess plutonium is already in spent fuel). But little progress has been made in implementing the 2000 agreement.[233] After years of delay and

[227] See USEC (formerly the U.S. Enrichment Corporation), "Megatons to Megawatts," available at http://www.usec.com/megatonstomegawatts.htm as of 30 July 2008).

[228] U.S. Department of Energy, National Nuclear Security Administration, "U.S. and Russia Cooperate to Eliminate Dangerous Nuclear Material: 10 Metric Tons of Russian HEU Successfully Downblended" (Washington, D.C.: NNSA, 24 April 2008, available at http://nnsa.energy.gov/news/1987.htm as of 30 July 2008).

[229] For an overview, see Matthew Bunn and Anatoli Diakov, "Disposition of Excess Highly Enriched Uranium," in *Global Fissile Materials Report 2007* (Princeton, NJ: International Panel on Fissile Materials, October 2007, available at http://www.fissilematerials.org as of 30 July 2008), pp. 24-32.

[230] Data provided by NNSA, October 2008. The United States declared 174 tons of HEU excess to its military needs in the 1990s, and more recently declared an additional 200 tons as excess to *weapons* needs, though most of that new declaration is to be retained as HEU for eventual use as naval fuel. 217 tons represents NNSA's estimate of the combined amount from these two stocks that will require disposition by blending.

[231] See Bunn and Diakov, "Disposition of Excess Highly Enriched Uranium."

[232] International Panel on Fissile Materials, *Global Fissile Material Report 2007* (Princeton, N.J.: IPFM, 2007, available at http://www.fissilematerials.org/ipfm/site_down/gfmr07.pdf as of 30 July 2008), pp. 9-18.

[233] For an overview, see Matthew Bunn and Anatoli Diakov, "Disposition of Excess Highly Enriched Uranium," and "Disposition of Excess Plutonium," in *Global Fissile Materials Report 2007* (Princeton,

immense growth in estimated costs, a plutonium-uranium mixed oxide (MOX) fuel fabrication plant is under construction at Savannah River, but it is not expected to start up until 2016. NNSA's latest published estimates indicate a life-cycle cost for the MOX facility of some $7.2 billion (not counting the substantial cost of the pit disassembly and conversion facility). NNSA argues that the spiralling costs result from delays caused by limited and uncertain annual appropriations, the need to modify French designs to meet U.S. codes, post-9/11 security requirements, and the like, but it remains a mystery why a facility with far less capability than comparable French facilities will cost many times as much to build. Even once the expected $2 billion in expected revenue from MOX sales is subtracted, the estimated life-cycle cost still comes to over $120 million per ton of excess plutonium.[234] DOE is still examining how to address other excess plutonium that is not pure enough to be used as MOX.

On the Russian side, the United States and Russia have largely abandoned the previous plan of using MOX in light-water reactors, as in the United States, and have settled instead on an approach focusing on using plutonium fuel in the existing BN-600 fast neutron reactor and the larger BN-800 reactor now under construction. Here, too, there have been years of delay while the two sides settled on the technical approach, resolved a prolonged dispute over nuclear liability, and looked for international financing for the effort. While a variety of understandings in principle have finally been reached on the new fast-reactor-centered approach over the last two years, little on-the-ground progress has been made, pending resolution of remaining issues. The United States has pledged $400 million to support the Russian disposition program, but in the omnibus appropriation passed in late 2007, Congress rescinded all unspent funds appropriated for this purpose. Whether the next Congress will be prepared to provide hundreds of millions of dollars to support a disposition program based on fast reactors remains an open question. Critics charge that this approach will accelerate Russia's shift toward a plutonium economy that will involve production, reprocessing, and transport of tons of new plutonium every year. Supporters of the effort counter that the fast reactor approach, like the earlier light-water reactor approach, will convert tens of tons of plutonium into spent fuel, which, under the terms of the 2000 accord, cannot be reprocessed until disposition is complete. The United States and Russia are now discussing modifications of the 2000 accord to reflect the new approach, along with approaches to monitoring and transparency. In any case, as with HEU, both the United States and Russia appear to plan to retain enough plutonium in their military stockpile to support an arsenal of many thousands of nuclear weapons.[235]

Ending further production. No discussions are currently underway regarding any form of agreement or understanding to end nuclear weapons production. The United States, however, has not been

N.J.: International Panel on Fissile Materials, October 2007, available at http://www.fissilematerials.org/ipfm/site_down/gfmr07.pdf as of 30 July 2008), pp. 33-42.

[234] Total project cost for construction is $4.8 billion. Operations and maintenance is estimated at $2.4 billion. See U.S. Department of Energy, *FY 2009 Congressional Budget Request: Other Defense Activities* (Washington, DC: DOE, February 2008), pp. 125-141, available at http://www.cfo.doe.gov/budget/09budget/Content/Volumes/Volume2.pdf, as of 11 November 2008. The per-ton calculation assumes, over-generously, that the 9 tons of excess plutonium announced in 2007 is entirely additional to the 34 tons covered under the 2000 disposition agreement and costs nothing to process.

[235] See discussion in Bunn and Diakov, "Disposition of Excess Plutonium."

producing nuclear weapons for many years, and the same may be true in Russia, and possibly Britain, France, China, and Israel as well. Nuclear weapons production in North Korea has presumably been stopped by the shut-down of production of additional material to be used for weapons. India and Pakistan, however, are still producing nuclear materials for weapons, and presumably fabricating that material into additional nuclear weapons. The United States, Russia, France, and Britain have all indicated that they have stopped producing plutonium and HEU for weapons and do not plan to do so again; China has informally stopped production without making any pledge not to produce in the future. North Korea, as already noted, has shut down and disabled its plutonium production facilities, and available indications suggest that Israel is not producing plutonium for weapons. Thus, an informal moratorium on production of nuclear material for weapons appears to exist for all states except India and Pakistan. Efforts to convert this moratorium into binding fissile material cutoff treaty (FMCT) have been deadlocked for years, however, and show little immediate prospect of revival. The Bush administration's proposal that the treaty not include any international verification is opposed by many other countries and is not likely to serve as a basis for an international consensus to move forward.[236] There has been major progress in the past year, however, in the effort to help Russia shut down its remaining plutonium production reactors (which have operated in recent years only to provide heat and power to nearby communities). With alternative coal capacity now available, the two reactors at Seversk shut down permanently in 2008, and NNSA hopes that the final remaining reactor, at Zheleznogorsk, will shut down in 2010.[237] At the same time, the Bush administration has done little to end the buildup of large stockpiles of civilian separated plutonium, which is also weapons-usable, and which is accumulating far faster than stocks of weapons material are. Indeed, the widespread perception that the administration has endorsed reprocessing in the Global Nuclear Energy Partnership (GNEP)—despite the administration's rhetorical opposition to accumulation of "pure plutonium"—has, if anything, encouraged continued reprocessing.

Monitor: Monitoring Nuclear Stockpiles and Reductions

Declarations and monitoring of nuclear stockpiles can also be an important tool to reduce the risk of nuclear terrorism. By opening sites to foreign visitors, such measures ease the security obstacles to nuclear security cooperation; they can motivate states to fix obvious security and accounting problems to avoid embarrassment; and they create a multinational discipline on the quality of accounting measures that is not present when no such measures are in place and states are left to determine for themselves what control and accounting measures to take.[238]

[236] For an in-depth discussion of a fissile material treaty and approaches to verifying it, see International Panel on Fissile Materials, *Global Fissile Materials Report 2008* (Princeton, N.J.: IPFM, forthcoming) 2008, available at http://www.ipfmlibrary.org/gfmr08.pdf as of 11 November 2008.

[237] See U.S. Department of Energy, National Nuclear Security Administration, "NNSA Announces the End of Plutonium Production in Seversk, Russia: Only One Russian Plutonium Producing Reactor Remains" (Washington, D.C.: NNSA, 5 June 2008, available at http://nnsa.energy.gov/news/2041.htm as of 30 July 2008).

[238] For a discussion of this connection, see, for example, 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_

Today, all stockpiles of plutonium and enriched uranium in non-nuclear-weapon states party to the Nonproliferation Treaty (NPT) are inspected by the IAEA (in a process known as "safeguards"). Just because material is under safeguards does not mean it is well secured; there are no blue-helmeted UN guards protecting material that is under safeguards. Safeguards in themselves do not secure material against theft—or even inspect the quality of security arrangements—but they help ensure that nuclear material is reasonably well accounted for, and in some cases in the past such inspections have helped identify and correct particularly glaring security deficiencies.[239]

By contrast, most stockpiles of nuclear weapons, plutonium, and HEU in weapon states are not subject to any international monitoring. [240] Civilian plutonium and HEU in France and Britain are subject to Euratom safeguards, and some 12 tons of U.S. excess HEU and plutonium has been under IAEA safeguards for years. The United States and Russia implement bilateral transparency measures for the HEU Purchase agreement, to confirm that the LEU comes from HEU, and that the LEU is used in the United States only for peaceful purposes. The United States and Russia also carry out limited monitoring measures at shut-down plutonium production sites, and at the sites where plutonium from ongoing production in Russia is stored; the two sides have been discussing transparency measures for the Mayak Fissile Material Storage Facility (built with U.S. financing) for years, but have not reached agreement. The United States and Russia are also discussing potential transparency measures for their plutonium disposition agreement, though there, too, there is as yet no agreement. U.S. and Russian experts have worked together to develop a variety of technologies and procedures that could be applied to confirming warhead dismantlement and monitoring stocks of fissile materials without compromising sensitive information, but have not agreed to implement such measures. The United States and Russia have not even told each other how many nuclear weapons they have; those weapons are not under any form of bilateral or international transparency; and the two countries do not carry out any form of verification of nuclear weapons dismantlement (in contrast to verification of dismantlement of the missiles, bombers, and submarines that might carry such weapons). Under the Trilateral Initiative, the United States, Russia, and the IAEA worked out legal mechanisms, technologies, and procedures for the IAEA to monitor excess stocks of nuclear material, even in classified forms, without revealing sensitive information, but the initiative has effectively been abandoned, and no material has ever been placed under monitoring using these procedures. There is, in short, very little progress toward actually implementing international transparency and monitoring in the nuclear weapon states—which will be crucial if the world is to move toward very deep reductions in nuclear arms and their eventual elimination.

research/cnwm/cnwm.pdf as of 28 March 2008), pp. 147-148.

[239] The IAEA's safeguards agreements with individual states forbid the agency from using information from safeguards inspections for any non-safeguards purpose, or providing it to anyone who does not need to know it to implement safeguards, such as security experts. Hence, when IAEA inspectors first went to the newly independent states that had been part of the Soviet Union and noticed substantial security problems, the IAEA invited the ambassadors from those countries for discussions, and offered them the IAEA's services in assessing and improving physical protection measures—an offer that was usually accepted. Interview with former Deputy Director-General for Safeguards Bruno Pellaud, May 2008.

[240] For discussion, see, for example, William Walker and Lawrence Scheinman, "International Safeguards in the Nuclear Weapon States," in IPFM *Global Fissile Materials Report 2007*, pp. 67-81.

Still Much to Do to Reduce the Danger

As this chapter has made clear, a great deal is being done to reduce the risk of nuclear terrorism. There can be little doubt that the danger today is much less than it would have been had these programs never existed. The world owes a debt of gratitude to the hundreds of men and women who have struggled to move these efforts forward.

But the danger of nuclear terrorism remains very real. As this chapter has also made clear, there are many areas where only limited progress has yet been made, or the needed steps are not yet on the agenda. Many nuclear sites around the world still have protections in place that are demonstrably insufficient to protect against a significant group of well-trained, well-armed outsiders, or a determined and sophisticated insider thief—and a substantial number of these sites are not targeted by any current program to upgrade security. There are still no effective global standards for nuclear security that would ensure that all nuclear weapons and stocks of weapons-usable nuclear material were protected against the kinds of threats terrorists and thieves have shown they can pose. Current programs to convert HEU-fueled reactors and remove vulnerable nuclear material exclude nearly half of the world's currently operating HEU-fueled research reactors, and would leave some four-fifths of the civil HEU outside of the United States and Russia where it is. No program yet exists to given little-used HEU-fueled research reactors incentives to shut down. And many of the key decision-makers around the world who could change nuclear security continue to dismiss the nuclear terrorism threat and the need for action to address it—an attitude that inevitably undermines security culture and makes it difficult to reach agreement on substantial new measures to address the threat. The question former Senator Sam Nunn has long asked remains very relevant: on the day after a terrorist nuclear attack, what would we wish we had done to prevent it? Why aren't we doing that now?

3 SECURING NUCLEAR STOCKPILES: QUANTITATIVE INDICATORS

The qualitative assessment in Chapter 2 makes clear that much has been accomplished to reduce the risks of nuclear theft and terrorism. But much more remains to be done. The danger remains unacceptably high.

This chapter offers a series of quantitative indicators of progress in securing and consolidating global nuclear stockpiles. As the last chapter emphasized, difficult-to-quantify factors, from the quality of guard forces to the strength of the staff's security culture, are at least as important as measurable items such as how many buildings are equipped with what types of equipment. Hence, the numbers presented here should not be considered as anything more than rough indicators of the state of a more complex picture.

In the absence of hard data on the real effectiveness of nuclear security systems around the world, I rely, in this chapter, 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) buildings or warhead sites where particular types of U.S.-sponsored security and accounting upgrades have been completed, and (b) buildings or sites where the potential nuclear bomb material has been removed entirely, eliminating the theft risk from that location. Because of limitations on the available data, I focus here on a small number of indicators, primarily focused on countries where the U.S. government has been providing assistance to improve nuclear security or consolidate nuclear materials.

I have relied on official government measures and data where possible, but in some cases these are not available. Both the National Nuclear Security Administration (NNSA) at the U.S. Department of Energy (DOE) and the Cooperative Threat Reduction (CTR) program of the U.S. Department of Defense (DOD) publish fairly detailed measures of performance for their programs to improve security for nuclear warheads and materials,[1] and this chapter draws heavily on that data, supplemented with interviews with U.S. officials, foreign officials, and other participants in these programs. This year, the U.S. government has provided data through the spring of 2008, making the information I can report more up-to-date than it has been in previous editions of *Securing the Bomb.*

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

[1] The detailed justifications of their budget proposals supplied by the agencies to Congress contain performance information and targets for each major activity; see, for example, U.S. Department of Energy, *FY 2009 Congressional Budget Request: National Nuclear Security Administration*, vol. 1, DOE/CF-024 (Washington, D.C.: DOE, 2008; available at http://www.cfo.doe.gov/budget/09budget/Content/Volumes/Volume1a.pdf as of 9 June 2008). The departments also publish assessments of their own performance, which often contain additional data. See, for example, U.S. Department of Energy, *Annual Performance Report Fiscal Year 2007* (Washington, D.C.: DOE, 2008; available at http://www.cfo.doe.gov/CF1-2/2007APR.pdf as of 26 June 2008). 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.

secure and accounted for to standards that would ensure they are protected against the kinds of threats terrorists and criminals have shown they can pose, or for the other elements of a comprehensive approach to preventing nuclear terrorism. Nor has the U.S. government 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 in this complex endeavor and where prolonged delays suggest the need for a change in approach.[2] Until that occurs, there remains an important role for reports such as this one, which attempt to provide the best progress assessments practicable from outside the government.

Most of the cooperative work to improve security for nuclear stockpiles that has occurred to date has been focused on Russia and the other states of the former Soviet Union, since the immediate nuclear dangers following the collapse of the Soviet Union launched the Nunn-Lugar effort. But it is increasingly clear that the need to improve security for nuclear stockpiles is a global problem: in essentially every country where nuclear weapons, highly enriched uranium (HEU), or separated plutonium exists—including the United States—there is more to be done to ensure these stockpiles are secure. Hence, the first two indicators below focus on security upgrades for nuclear materials and nuclear warheads in the former Soviet Union, while the three remaining indicators focus on global progress—focusing on upgrades and material removals from HEU-fueled research reactors, for which more numerical data are available.

[2] 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.

Indicator 1: Security Upgrades on Former Soviet Buildings Containing Nuclear Material

Fraction accomplished. NNSA currently plans to help Russia and the other Eurasian states carry out upgrades of security and accounting measures for 225 buildings containing plutonium or HEU.[3] This includes 210 buildings in Russia and 15 buildings in the other Eurasian states. This represents a very large fraction, but not all, of the buildings in Russia where these materials exist. There is still no agreement for U.S. help in upgrading security at Russia's two remaining nuclear warhead assembly and disassembly sites, where huge quantities of nuclear material are thought to exist, and there are probably a limited number of other buildings at nuclear weapons complex sites that Russia has not yet made available for nuclear security cooperation.[4] Conservatively, there are probably at

[3] U.S. Department of Energy, *FY 2009 NNSA Budget Request*, p. 497.

[4] The remaining nuclear weapons assembly-disassembly sites, at Lesnoy (formerly Sverdlovsk-45) and Trekhgornyy (formerly Zlatoust-36) are among the most sensitive facilities in Russia, and presumably have extensive security measures in place. Nevertheless, at every site where U.S. experts have gained access, including major nuclear weapons complex sites, it has usually not taken long for U.S. and Russian experts to agree on a substantial list of needed physical protection, material accounting, and material control upgrades. As one example suggesting the likelihood of additional sensitive buildings at other sites, in 1995, a Russian expert who had been on a government team investigating safety practices at Seversk (formerly Tomsk-7) reported that one building there housed 23,000 "pits," the primary fission components of nuclear weapons. Valerii F. Menshikov, "On the Situation with Storage of Plutonium and Enriched Uranium in Tomsk-7," *Yaderny Kontrol*, no. 2 (February 1995). U.S.-sponsored upgrades have been carried out for a large number of buildings at Seversk, but none with that kind of a stockpile. Interview with NNSA official, December 2007.

least 20 buildings with weapons-usable material in Russia that are not included in current upgrade plans, for a total in the range of 245 such buildings in Russia and the other Eurasian states.[5]

In addition, NNSA has so far only been financing extensive upgrades for buildings thought to contain plutonium or HEU containing 75 percent or more U-235, and has in most cases not been providing upgrades for sites with only irradiated HEU.[6] HEU at much less than 75 percent enrichment can readily be used to make nuclear bombs, and much irradiated HEU at research reactors is not self-protecting and also poses a serious danger of theft. If buildings containing these other categories of HEU were included, the total number of buildings requiring upgrades would increase.

NNSA sponsors two levels of upgrades: 1) so-called "rapid upgrades", usually done within six months, such as bricking over windows, hardening doors, and installing portal monitors and 2) "comprehensive upgrades," which are complete systems of intrusion detectors, barriers, and material control and accounting designed to be able to protect against outsider or insider threats with a specified level of capability, which typically take two years or more to install. In nearly all cases, buildings receive rapid upgrades first, followed by comprehensive upgrades, so the buildings with comprehensive upgrades are a subset of the buildings that have at least rapid upgrades in place.[7]

As of the end of FY 2008, comprehensive security and accounting upgrades had been completed for 166 of the buildings in Russia, while at least rapid upgrades had been completed for 28 more, for a total of 194 with either comprehensive or rapid upgrades completed.[8] Upgrades had been completed for all of the sites in other Eurasian states, including 15 buildings with weapons-usable nuclear material, although further upgrades are still underway for one building at Sosny, in Belarus.[9] All told, then, comprehensive upgrades had been completed for 181 buildings by the end of FY 2008, representing 70-75 percent of the total number of buildings in the former Soviet Union with weapons-usable nuclear material, or just over 80

[5] For a discussion, see Matthew Bunn, *Securing the Bomb 2007* (Cambridge, Mass.: Project on Managing the Atom, Harvard University, and Nuclear Threat Initiative, 2007; available at http://www.nti.org/securingthebomb as of 28 March 2008), pp. 65-66.

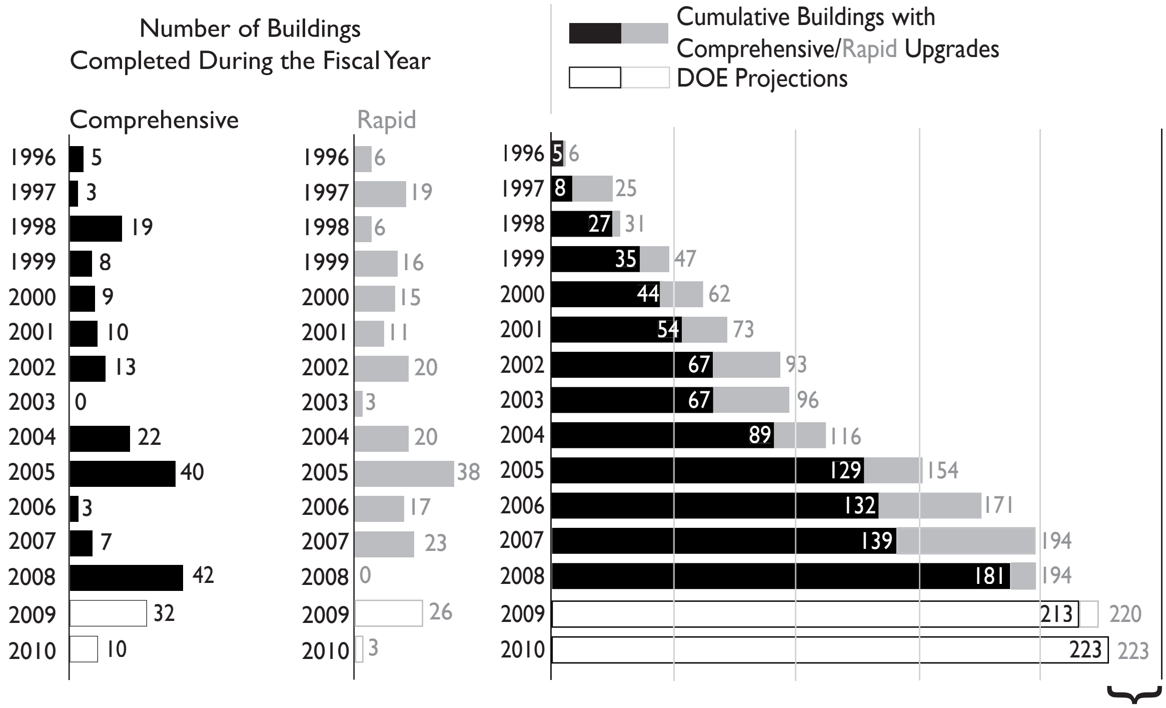
[6] Personal communication from Laura Holgate, Vice President Russia/Newly Independent States (NIS) Programs, NTI, September 2008.

[7] There are two buildings at Zheleznogorsk that went straight to comprehensive upgrades without ever receiving rapid upgrades, and two buildings at Seversk that were judged only to require rapid upgrades. Since these numbers cancel each other, the total number of buildings planned for comprehensive upgrades is the same as the total number planned for rapid upgrades. Data provided by NNSA, June 2008.

[8] Data on comprehensive upgrades provided by NNSA, June 2008; rapid upgrades data estimated based on having accomplished one-half of the goal for the fiscal year (with a total of 179 buildings in Russia having comprehensive or rapid upgrades completed by the end of FY 2007, and 201 planned by the end of FY08). The buildings with comprehensive upgrades completed by May 2008 included 71 of 139 buildings where comprehensive upgrades are planned in the Rosatom weapons complex; 37 of 41 buildings where upgrades are planned in the Rosatom civilian complex; all nine of the non-Rosatom civilian buildings where upgrades are planned; and all 21 of the Russian Navy buildings where upgrades are planned. Buildings completed is 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. 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. Previous reports in this series have also reported data on the less informative materials measure, but NNSA no longer publishes up-to-date data on this metric.

[9] Data provided by NNSA, June 2008.

Figure 3.1: FSU Buildings with Security Upgrades



There exists a publicly unknown number of buildings containing weapon-usable nuclear material in Russia on which the United States and Russia have never agreed to cooperate.

Source: Data provided by NNSA, June and October 2008

percent of the number where DOE currently plans to support upgrades. At least rapid upgrades had been completed for roughly 209 buildings, roughly 85 percent of the total, or approximately 93 percent of the buildings where DOE plans to provide upgrades.

Rate of progress. U.S. and Russian experts are now racing to complete the nuclear security upgrades agreed to at the Bratislava summit—covering 176 of the buildings in Russia[10]—by the end of 2008. They have already completed comprehensive upgrades at nearly 40 buildings during FY 2008, with ten more to go before the end of the calendar year. To meet the challenging agreed targets, NNSA officials and their Rosatom counterparts have been on the phone frequently attempting to clear away obstacles at each site as they arise.[11] The additional buildings that are not slated to be completed by the end of 2008 were agreed to after the Bratislava plan was laid out in 2005. NNSA plans to complete these rapidly as well, with 24 more buildings slated for comprehensive upgrades in FY 2009, and the final ten in FY 2010.[12] Figure 3.1 shows how many buildings have received comprehensive or rapid upgrades each year, and projections for the future.

[10] Data provided by NNSA, June 2008. NNSA's budget justifications indicate that the Bratislava commitment includes "approximately 215" buildings, a much larger number. See U.S. Department of Energy, *FY 2009 NNSA Budget Request*, p. 495. NNSA reports, however, that this figure mistakenly included the 15 buildings outside Russia, and that 22 buildings at Sarov (formerly Arzamas-16) have been "reclassified" as being outside the Bratislava scope, to be completed after the end of 2008. Data provided by NNSA, June 2008.

[11] Interview with NNSA official, April 2008.

[12] U.S. Department of Energy, *FY 2009 NNSA Budget Request*, p. 497. Confirmed in data provided by NNSA, June 2008.

Other security and accounting improvements. U.S. and other international assistance programs have helped with a wide range of other improvements in addition to installing upgraded security and accounting equipment at buildings. These have included, among other items, training for security and accounting personnel and for nuclear guards; help with strengthening nuclear security and accounting regulations; secure trucks and railcars for transporting nuclear material; efforts to consolidate and blend down nuclear material; and work on promoting strong security cultures at selected sites. As discussed in Chapter 2, several of these efforts have made significant progress, though this work 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.[13] In addition, the 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 early 2008, however, transparency arrangements for the facility had not been finalized, despite discussions that have been ongoing intermittently since the mid-1990s.[14]

Indicator 2: Security Upgrades on Russian Sites Containing Warheads

Fraction accomplished. DOD and NNSA are working with Russian counterparts to install modern security systems at 97 Russian nuclear warhead sites (73 NNSA and 24 DOD). This appears to represent all or nearly all permanent storage sites for tactical and strategic nuclear weapons in Russia.[15] But it does not include: (a) a significant number of temporary sites, such as areas at bomber or submarine bases where warheads may be for hours or days in the course of being loaded or unloaded, or rail transfer points where warheads may be for some time during transports; (b) front-line tactical deployment sites;[16] and (c) a small number of warhead sites for which Russia requested help upgrading security and the United States declined to provide it on policy grounds.[17]

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

[14] U.S. Department of Defense, *Cooperative Threat Reduction Annual Report to Congress: Fiscal Year 2009* (Washington, D.C.: DOD, 2008; available at http://www.dtra.mil/documents/oe/ctr/FY09 percent20CTR percent20Annual percent20Report percent20to percent20Congress.pdf as of 9 June 2008), p. 15.

[15] It is notable that while DOD used to assert that the sites being upgraded included "all permanent storage locations that contain strategic or tactical nuclear weapons," it now asserts only that the sites include "all *requested* permanent storage locations that contain strategic or tactical nuclear weapons," (emphasis added)—that is, all sites that (a) are permanent storage sites and not temporary sites; (b) that the United States believes really do contain nuclear weapons on a day-to-day basis, and (c) for which Russia requested assistance with security upgrades. See 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, and U.S. Department of Defense, *Cooperative Threat Reduction Annual Report to Congress: Fiscal Year 2009* (Washington, D.C.: U.S. Department of Defense, 2008), p. 13.

[16] Tactical deployment sites should no longer contain warheads, assuming all tactical warheads have been moved to central storage as Russia pledged in 1991-1992. However, the sites still exist, their units still train for nuclear missions, and would presumably receive warheads in a severe crisis.

[17] For a discussion of these categories of sites, see Bunn, *Securing the Bomb 2007*, pp. 68-69. In January

The total number of warhead sites in Russia is not publicly known, but appears to be in the range of 110-130, including both permanent and temporary sites, but not counting the front-line tactical sites that may no longer have warheads day-to-day.

All planned upgrades had been completed for 81 of these warhead sites by the end of FY 2008 (64 NNSA and 17 DOD).[18] This represents 82 percent of the sites where upgrades are planned, or 60-75 percent of the total number of sites.

Rate of progress. Here, too, U.S. and Russian experts are racing to meet the end-of-2008 deadline specified in the agreed plan worked out after the Bratislava summit. NNSA in particular appears to have made remarkable progress in FY 2007, completing upgrades at an additional 14 warhead sites (six more than they had planned), though progress then slowed in FY 2008.[19] DOD apparently completed four sites shortly after the end of FY 2007, for a total of 18 that year or shortly thereafter between the two agencies. Completing the Bratislava mandate during 2008 would require completing 16 additional sites in the remainder of 2008. That is potentially achievable, though it will be very challenging. When the program is completed, it will have assisted with security upgrades at 75-90 percent of the estimated total of nuclear warhead sites in Russia. Figure 3.2 shows the number of warhead sites where upgrades sponsored by DOE and by DOD have been completed for each year, and the plan for the coming year.

Other security and accounting improvements. 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 help 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 2007, carrying an estimated 15-20 warheads on each trip; by the end of FY 2007, DOD had sponsored a total of 374 such trips, moving roughly 5,500-7,500 Russian nuclear warheads to storage facilities or to dismantlement.[20] In FY 2007, DOD procured 40 armored vehicles for short-distance warhead transports, 15 of which were delivered to Russia during the fiscal year.[21] DOD is also procuring 100 armored railcars for secure warhead transport (replacing a larger number of railcars that

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

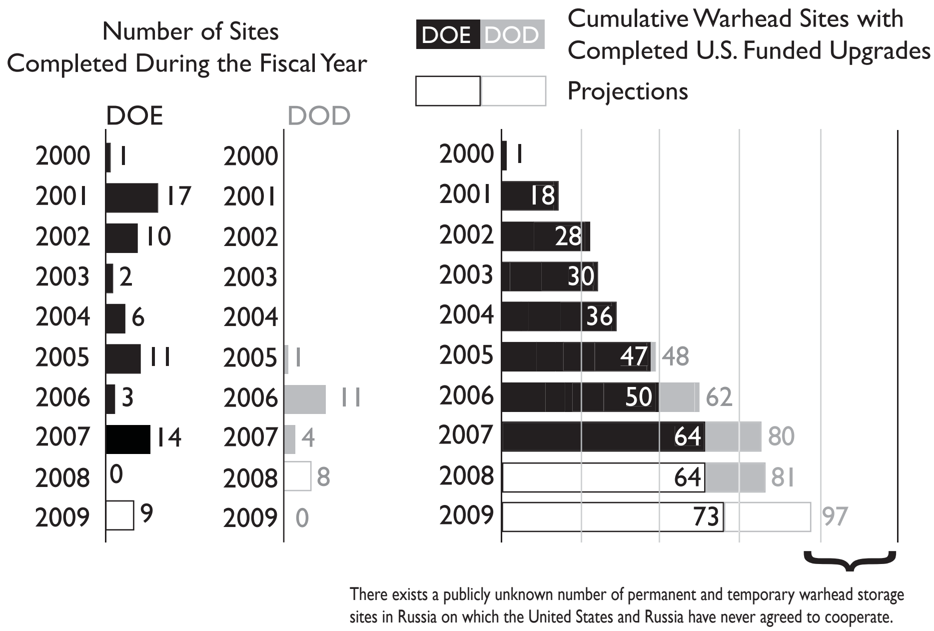
[18] NNSA reports that 64 warhead sites were completed by the end of FY 2007, and still had 64 as the figure in a September 2008 press release (which referred to 39 Navy sites and 25 Strategic Rocket Forces sites as completed, with upgrades at nine 12th Main Directorate sites still underway. See U.S. Department of Energy, National Nuclear Security Administration, "NNSA: Working to Prevent Nuclear Terrorism" (Washington, D.C.: NNSA, September 2008, available at http://www.nnsa.energy.gov/news/982.htm as of 22 October 2008), and U.S. Department of Energy, *FY 2009 NNSA Budget Request*, p. 497. The data on 17 DOD sites completed is from U.S. Department of Defense, *The Nunn-Lugar Scorecard* (Washington, D.C.: DOD, August 2008), available at http://lugar.senate.gov/nunnlugar/scorecard.html as of 22 October 2008. DOD reports that it had 12 sites completed by the end of FY 2007. See U.S. Department of Defense, *FY 2009 CTR Annual Report*, pp. 6, 13, 38.

[19] U.S. Department of Energy, *FY 2009 NNSA Budget Request*, p. 497.

[20] U.S. Department of Defense, *FY 2009 CTR Annual Report*, p. 2.

[21] U.S. Department of Defense, *FY 2009 CTR Annual Report*, p. 13.

Figure 3.2: Warhead Sites with Security Upgrades



Source: Data provided by NNSA, June and October 2008; U.S. Department of Defense, *Cooperative Threat Reduction Annual Report to Congress: Fiscal Year 2009* (Washington, D.C.: DOD, 2008); U.S. Department of Defense, "Nunn-Lugar Scorecard" (Washington D.C.: DOD, updated 20 October 2008).

are reaching the end of their service lives), and has provided armored escort railcars, 15 of which are now being equipped with transponders for continuous satellite communication.[22] 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 financing the establishment of an additional center in the Far East.[23] A project to set up an Automated Inventory Control and Management System (AICMS) now provides computerized monitoring of warhead inventories at 20 Russian sites, and is being expanded to cover 13 additional sites.[24] Further, the United States has financed equipment and training to improve Russia's personnel reliability program for individuals with nuclear weapon responsibilities; guard force equipment and training; and a variety of emergency response equipment.[25]

Global Measures

As discussed in Chapter 2, no comprehensive measures of progress in improving

[22] U.S. Department of Defense, *FY 2009 CTR Annual Report*, p. 15.

[23] U.S. Department of Defense, *FY 2009 CTR Annual Report*, p. 14.

[24] U.S. Department of Defense, *FY 2009 CTR Annual Report*, p. 14.

[25] 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).

the global nuclear security picture are available. Most countries consider the status of their nuclear security arrangements to be a closely guarded secret. 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. In this chapter, therefore, I 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, 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). In the discussion below, I provide measures of progress on all three of these steps.

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

Many countries have adopted IAEA physical protection recommendations in their domestic rules, and hence many HEU-fueled research reactors have security measures that comply with the IAEA recommendations without any U.S. or other assistance.[26] 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 at HEU-fueled reactors that do not fully comport with the recommendations or have requested assistance in meeting these recommendations. The U.S. government, other international donors, and the IAEA, working together, have upgraded all but a few of these to meet the IAEA recommendations (with most of the remaining sites that do not meet IAEA recommendations located in the United States).

Within the U.S. government, several programs are responsible for different portions of this work. NNSA'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). NNSA's GTRI program is charged with upgrading security where needed at HEU-fueled re-

[26] 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 especially 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).

search reactors in other foreign countries. Another part of NNSA 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.[27] 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 2008, the United States (and other countries in several cases) had provided assistance to upgrade security at roughly 25 HEU-fueled research reactors or related HEU sites outside of Russia and the United States to the level of the IAEA recommendations—13 in the non-Russian states of the former Soviet Union (representing 100 percent of the HEU sites there), and 14 more elsewhere. The 13 reactors or related HEU facilities upgraded are at 11 sites in the non-Russian states of the former Soviet Union, including:

- the Nuclear Research Center near Salaspils in Latvia (from which all HEU has now been removed);
- three sites in Ukraine, including the Kharkiv Institute of Physics and Technology (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 two shut-down HEU-fueled training reactors), and the Kiev Institute of Nuclear Research (which still has an operating HEU-fueled research reactor);
- four sites in Kazakhstan, including the Ulba Metallurgical Plant at Ust-Kamenogorsk (a fuel fabrication facility which no longer has HEU on-site because of Project Sapphire in 1994, which airlifted nearly 600 kilograms of HEU from this facility, and the completion of an HEU-to-LEU blending project sponsored by the Nuclear Threat Initiative), the BN-350 Fast Breeder Reactor at Aqtau (which is no longer operating and no longer has fresh HEU on-site, because the material was shipped to Ulba for blending under the NTI-sponsored project just mentioned, though the 300 tons of spent fuel contains some three tons of better-than-weapon-grade plutonium, and may contain some material which remains barely above the 20 percent enrichment line that defines HEU), the Institute of Atomic Energy at Kurchatov (the former Semipalatinsk test site, which still has two operating HEU-fueled reactors), and the Institute of Nuclear Physics in Alatau, Kazakhstan (which still has one operating HEU-fueled reactor, along with fresh HEU);
- two sites in Uzbekistan (the Institute of Nuclear Physics and the Photon facility); 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).

The upgraded sites elsewhere include:

[27] 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 NNSA, the group responsible for international safeguards.

- the RPI reactor at the Technological and Nuclear Institute in Portugal (Portuguese acronym ITN);
- the Maria and Eva reactors in Poland;
- the reactor at the Nuclear Research Institute at Rez, in the Czech Republic;
- the Demokritos (GRR-1) reactor in Greece (from which all HEU has since been removed);
- the reactor at the Atomic Energy Research Institute in Budapest, Hungary (Hungarian acronym AEKI);
- the reactors at Pitesti and Magurele, Romania;
- the reactors at the Vinca Institute of Nuclear Sciences, in Serbia;
- the reactor at Serpong, in Indonesia;
- the facilities at Lo Aguirre and La Reina in Chile;
- the Slowpoke reactor in Jamaica; and
- the reactor at Dalat, in Vietnam.[28]

NNSA currently judges that only four additional sites outside Russia and the United States require such upgrades.[29]

Ironically, most of the remaining HEU-fueled reactors that arguably do not meet IAEA physical protection recommendations are within the United States. As noted in Chapter 2, research reactors regulated by the NRC are exempt from most of the security requirements the NRC imposes on other sites with HEU; NRC regulations for HEU-fueled research reactors are significantly weaker than the IAEA recommendations.[30] GTRI has begun helping some U.S. research reac-

[28] Compiled from data provided by NNSA, December 2005, August 2007, July 2008, and October 2008.

[29] Data provided by NNSA, July 2008.

[30] 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 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

tors that volunteer for upgrades going beyond NRC requirements, but most of the eight remaining NRC-regulated HEU-fueled research reactors have not yet been upgraded. The first two U.S. reactors where security upgrades have been implemented are the HEU-fueled reactor at the University of Missouri and the recently-converted reactor at Oregon State University.[31] GTRI plans to help upgrade 5 additional reactors in the United States in FY 2009, and has tripled the budget of this effort from $1 million to $3 million.[32] All told, NRC and the Department of Homeland Security (DHS) have asked GTRI to help with security upgrades at 30 U.S. reactors, both HEU-fueled and LEU-fueled.[33]

When the entire global set of HEU-fueled research reactors is considered, including those in Russia and the United States, it appears that upgrades sufficient to comply with IAEA physical protection recommendations have been completed for something in the range of 90 percent of the facilities that required them.[34]

This estimate 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.[35] 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).[36] There may

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

[31] Data provided by NNSA, October 2008.

[32] Data provided by NNSA, October 2008.

[33] Data provided by NNSA, July 2008.

[34] Author's estimate. The reactors estimated to have been upgraded to a level sufficient to meet IAEA recommendations include all of the HEU-fueled research reactors in Russia and the former Soviet Union, and 14 elsewhere.

[35] 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).

[36] 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 (Washington, 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).

be a significant number of sites with irradiated HEU fuel that is not self-protecting by the IAEA standard and which therefore require substantial 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. Several reactors were upgraded during FY 2007-FY2008, and NNSA expects to complete the remaining upgrades it believes are necessary by the end of 2010.[37] For the most important of the facilities still on the list, however—the Pelindaba facility in South Africa—there was still no agreement to cooperate on security upgrades as of the fall of 2008.

Sustainability. NNSA typically provides support for fixing and replacing systems it pays to install for a limited period. GTRI has provided funds to the IAEA Office of Nuclear Security to provide training and other services to these sites to help with sustainability. But the reality is that most of these sites have little revenue, and may have difficulty affording to sustain extensive security measures. 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 over the long haul.

Indicator 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 stock 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 site is very low. A strong argument can be made that UN Security Council Resolution 1540, which legally requires every state with nuclear weapons or materials to provide "appropriate effective" security and accounting for them, creates a binding obligation to protect all sites with weapons-usable nuclear materials against the kinds of threats that terrorists and criminals have shown they can pose.[38]

Far less progress has been made in achieving this more demanding objective; except in Russia and the other states of the former Soviet Union, current security upgrade programs are focused on meeting IAEA recommendations, not on putting in place systems capable of defeating all plausible threats at that site. Here, I count a reactor as being upgraded to a level sufficient to meet the threat if (a) it has received extensive security upgrades or is known to have other security measures in place that seem likely to be able to defeat plausible insider and outsider threats where it is located; or (b) it has received less extensive upgrades, but has a stockpile of weapons-usable material on-site that is far less than needed for a bomb.[39]

[37] Data provided by NNSA, June 2008.

[38] Matthew Bunn, "'Appropriate Effective' Nuclear Security and Accounting: What is It?" presentation to the joint Global Initiative/UNSC 1540 Workshop on "Appropriate Effective Material Accounting and Physical Protection," Nashville, Tenn., 18 July 2008, available at http://belfercenter.ksg.harvard.edu/files/bunn-1540-appropriate-effective50.pdf as of 1 August 2008).

[39] Specifically, if a reactor has received security upgrades, and available information suggests that it

In Uzbekistan, for example, the VVR-SM reactor has received comprehensive security upgrades, GTRI has helped the facility convert from HEU to LEU fuel, and GTRI has helped remove all of the fresh HEU and most of the irradiated HEU, leaving only a few kilograms of irradiated 36 percent enriched material posing a very modest nuclear terrorism hazard. This is a tremendous step forward, given the large terrorist risks previously posed by the tens of kilograms of HEU that once existed in Uzbekistan (home of an armed Islamic extremist movement linked to al-Qaeda). But assessing progress in meeting these standards 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, my estimates for this measure should be understood as quite uncertain, intended to be illustrative, not definitive.

Based on the limited data publicly available, I estimate that roughly 25 percent of the global total of HEU-fueled research reactors and related facilities that required security upgrades to be able to defeat plausible threats as of the early 1990s have received such upgrades. This includes HEU-fueled reactors in Russia at civilian sites which have received comprehensive upgrades and have only modest stocks of HEU on-site;[40] HEU-fueled reactors located in Russian closed cities that have received comprehensive upgrades (and where outsider threats are limited by the security associated with the closed city, and insider threats are constrained by a heavier FSB presence than at civilian sites);[41] and HEU-fueled reactors elsewhere that have received security upgrades and have only modest stocks of HEU on-site.

Rate of progress. It appears that in the two years since the data cutoff for the previous edition of *Securing the Bomb,* 5-10 reactors have joined the group that has been upgraded to a level sufficient to reduce the risk of theft to a low level, given demonstrated terrorist and criminal capabilities in the countries where they exist. GTRI has adopted a default DBT that would significantly reduce the risks of nuclear theft, if the hoped-for level of security can be achieved and sustained. Wherever this new approach is implemented, it is likely to be sufficient to reduce the risk of nuclear theft to a moderately low level for those sites with

has less than a "Category I" quantity of HEU—defined in IAEA recommendations and U.S. rules as 5 kilograms of U-235 contained in HEU, requiring the highest level of security—I consider the reactor to be upgraded to a level sufficient to meet the threat.

[40] In Russia, as elsewhere in the world, few civilian facilities have security in place that would provide protection against attacks involving dozens of heavily armed, well-trained, suicidal attackers striking without warning, as occurred at Beslan and in the Nord-Ost theater seizure. Similarly, even upgraded security measures would likely not be proof against several well-placed insider thieves working together—a type of incident that has been all too common at other types of facilities in Russia, as discussed above. Hence, for civilian sites outside of closed territories, none of the reactors that have substantial stocks of HEU are plutonium are judged here to be upgraded to a level likely to be sufficient to protect against demonstrated terrorist and criminal capabilities.

[41] In making this estimate, I have assumed that the proportion of HEU-fueled research reactors located in the Rosatom weapons complex that have received comprehensive upgrades is the same as the proportion of the total buildings in the Rosatom weapons complex that have received such upgrades. As of the spring of 2008, 71 buildings in Rosatom's weapons complex containing weapons-usable nuclear material had received comprehensive upgrades, just over half of the 137 buildings in the Rosatom complex where such upgrades are planned. Data provided by NNSA, June 2008.

HEU stocks that are modest in size and quality. But sites with high-quality stocks in amounts sufficient to make a nuclear bomb would still pose dangerous (though much reduced) risks, as these sites would still not be able to defend against the larger, more capable threats that terrorists and criminals have demonstrated they can pose. As of the fall of 2008, only one HEU-fueled reactor had been upgraded to meet this new, higher security standard.[42] Future upgrades at HEU sites will be designed to meet this standard. To date, however, GTRI has not been returning to sites upgraded to meet IAEA recommendations to carry out further upgrades to meet this new default DBT, though it hopes to do so in the future for those sites that will continue to have HEU for a substantial period, resources and agreements permitting. In addition, as described above, the U.S. government is working with other governments to revise the IAEA recommendations, and if that revision, once agreed, calls for additional upgrades, GTRI will implement upgrades to allow sites to meet the new recommendations. Under current plans, it will likely be years before additional upgrades at already-upgraded sites begin.[43]

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 implemented. 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.

[42] Data provided by NNSA, October 2008.

[43] Data provided by NNSA, June 2008.

Indicator 5: Global HEU-Fueled Research Reactors With All HEU Removed

The next step, where possible, is to remove the nuclear materials entirely, 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. Even focusing in on HEU-fueled research reactors and related facilities, the U.S. government does not publish estimates of the total number of such facilities with HEU worldwide, or how many of them have had all of their HEU removed since U.S. efforts to take back such fuel were restarted in 1996.[44]

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 2008 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 several years) was in the range of 180-220

[44] 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. In this chapter, I focus on reactor numbers, as data on these is at least somewhat more accessible than data on sites.

facilities.[45] While many of these facilities were in the United States or Russia, they were quite widespread around the world. All told, as of the early 1990s there were significant stocks of U.S.-origin HEU in some 34 countries,[46] and Soviet-origin HEU in 18 countries;[47] with two countries (Germany and Romania) receiving HEU from both sources. Counting the United States and Russia themselves, this represents a total of some 52 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? Sixteen countries have sent back all of their U.S.-origin HEU eligible for return to the United States (though at least four of these still have other HEU), and 10 more have returned a portion of their U.S.-origin HEU.[48] At least four Soviet-supplied countries (Georgia, Iraq, Latvia, and Bulgaria) have been cleared of all of their HEU.[49] That leaves 38 U.S.-supplied

[45] Author's estimate, based on historical research reactor data in Ole Reistad and Styrkaar Hustveit, "HEU Fuel Cycle Inventories and Progress on Global Minimization," *Nonproliferation Review* 15, no. 2 (July 2008); Ole Reistad and Styrkaar Hustveit, "Appendix II: Operational, Shut Down, and Converted HEU-Fueled Research Reactors," *Nonproliferation Review* 15, no. 2 (July 2008; available at http://cns.miis.edu/pubs/npr/vol15/152_reistad_appendix2.pdf as of 3 July 2008). 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.

[46] 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 2 August 2008), p. 9.

[47] 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.

[48] The 16 countries which have returned all of their eligible U.S.-origin HEU include Argentina, Brazil, Chile, Columbia, Denmark, Germany, Greece, Italy, the Philippines, Portugal, Romania, Slovenia, South Korea, Spain, Sweden, and Thailand. See U.S. Department of Energy, National Nuclear Security Administration, "NNSA Completes Successful Year of U.S.-origin Nuclear Fuel Returns" (Washington, D.C.: NNSA, 7 October 2008; available at http://www.nnsa.energy.gov/news/2173.htm as of 14 October 2008). Chile, Denmark, Germany, and Romania, however, have additional HEU. GTRI hopes to remove all the HEU from Chile, Denmark, and Romania soon, but Germany still operates the large FRM-II research reactor with HEU fuel, is likely to have HEU on its soil for many years to come. Data provided by NNSA, June and October 2008. Earlier, Switzerland had been considered to have had all its U.S.-origin HEU removed, but NNSA has identified additional eligible U.S.-origin HEU in Switzerland. Data provided by NNSA, June 2007. For a listing of the other countries that have returned a portion of their eligible U.S.-origin HEU, see 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. That list includes 11 countries, but two of those (Greece and South Korea) have since completed the return of their U.S.-origin HEU, while, as just noted, Switzerland must be added to the list of countries where the return is not yet complete, for a total of 10.

[49] The HEU once present at a nuclear institute in the breakaway Georgian region of Abkhazia has

or Russian-supplied countries that still have HEU on their soil. In addition, HEU-fueled reactors have been established for the first time in Nigeria, Syria, and Ghana since the early 1990s (all supplied by China), but each of these has just under a kilogram of HEU. Excluding those, it appears that the number of countries with significant stocks of HEU on their soil has declined by roughly 25-30 percent. The number of countries with HEU on their soil is continuing to decline, as more HEU-fueled reactors convert or shut down and their HEU is removed.

Beyond *countries*, how many *facilities* have had all their HEU removed? All told, the available data suggests that since the mid-1990s, U.S.-funded programs have contributed to the removal of all HEU from roughly 50 HEU-fueled research reactors worldwide, representing roughly 25 percent of the estimated total.[50] This figure does not include facilities where countries may have removed HEU with no help from the United States; though these removals certainly contribute to the goal of minimizing HEU (and reduce the number of sites left to be addressed), they should not be counted as successes of U.S.-funded programs. 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 since the data cutoff for the last edition of *Securing the Bomb,* including facilities in Latvia, South Korea, Bulgaria, Portugal, Romania, and the United States. The pace is likely to accelerate over the next few years. Under GTRI's ambitious current plans, some 95 percent of the weapons-usable nuclear material it intends to remove would be removed by the end of FY 2010.[51] 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. Insufficient data are publicly available to estimate how many research reactors or associated facilities will still have HEU on-

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/BCSIA_content/documents/bleekglobalcleanout.pdf as of 9 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 7 August 2007). Iraq's Soviet-supplied and French-supplied HEU was removed after the 1991 Gulf War. The last Latvian HEU was removed in May 2008, and the last Bulgarian HEU in July 2008.

[50] In data provided in June and July 2008, NNSA's GTRI program listed 28 research reactors from which it had helped remove all HEU. To this must be added roughly eight U.S. HEU-fueled research reactors that have converted or shut down since the 1996 start date for this estimate, and whose fuel has been removed; four critical assemblies whose fuel has been removed but which were not listed in NNSA's tabulation (one each in the Czech Republic, Latvia, Libya, and Serbia); three critical assemblies at the Krylov Shipbuilding Institute in Russia, whose HEU was removed with help from the Material Consolidation and Conversion effort within NNSA's International Nuclear Materials Protection and Cooperation program; two Iraqi HEU-fueled reactors whose fuel was removed by the United Nations after the 1991 war; and the Ulba fuel manufacturing facility in Kazakhstan, whose HEU was removed in Project Sapphire. A small number of additional reactors may also have had their HEU removed with U.S. help during the period.

[51] U.S. Department of Energy, *FY 2009 NNSA Budget Request*, p. 531.

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.[52]

HEU removals in kilograms. NNSA 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.

Through the end of FY 2008, GTRI and its predecessor programs had helped with the removal of 1,948 kilograms of HEU from sites around the world, including 610 kilograms of Russian-origin HEU; 1,196 kilograms of U.S.-origin HEU eligible for the longstanding U.S. take-back offer; and 142 kilograms of HEU in the "gap" materials program, primarily U.S.-origin HEU not eligible for the ordinary take-back program.[53] This represents roughly 43 percent of the 4,501 kilograms of weapons-usable nuclear material GTRI hopes to help remove by 2015.[54] Since its establishment, GTRI has greatly accelerated the pace of these removals; GTRI removed over 420 kilograms of material in FY 2007 (beating its target by more than 100 kilograms).[55] The pace slowed in FY 2008, when the program helped remove 157 kilograms of HEU (more than 200 kilograms short of the target)—but then succeeded in removing 154.5 kilograms of irradiated HEU from Hungary, in an effort announced just after the turn of the fiscal year, along with just over 3 kilograms of fresh U.S.-origin HEU from Canada.[56] While GTRI's HEU and plutonium re-

[52] 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).

[53] Data provided by NNSA, October 2008. These figures include the material returned under the Foreign Research Reactor Spent Nuclear Fuel Acceptance Program since it was renewed in 1996, but it does not include earlier returns of U.S.-origin HEU, or removal efforts for Soviet-origin HEU before GTRI was established, such as Project Sapphire (HEU from Kazakhstan in 1994), Operation Auburn Endeavor (HEU from Georgia in 1998), and Project Vinca (HEU from Serbia in 2002). Nor does it include the HEU removed from Iraq by the United Nations after the 1991 war. When the U.S. offer to take back HEU it had supplied was renewed in 1996, the offer applied only to aluminum-based and TRIGA (Training, Research, and Isotopes—General Atomics) fuels, which the United States either had or planned to put in place processes for managing. Fresh, unirradiated HEU was not included in the offer at that time. See U.S. Department of Energy, "All Highly Enriched Uranium Removed from Latvia ". This does not include amounts removed from research reactors or other sites within the United States, or the amounts removed in the earlier Project Sapphire (Kazakhstan) and Operation Auburn Endeavor (Georgia) operations.

[54] Data provided by NNSA, October 2008. GTRI's removal goals have been reduced by more than 400 kilograms of HEU in the past year. For the earlier goal of 4,917 kilograms, see U.S. Department of Energy, *FY 2009 NNSA Budget Request*, p. 531.

[55] U.S. Department of Energy, *FY 2009 NNSA Budget Request*, p. 531.

[56] FY 2008 result from data provided by NNSA, October 2008. FY 2008 goal from U.S. Department of Energy, *FY 2009 NNSA Budget Request*, p. 531. For the Hungary shipment, see U.S. Department of Energy, National Nuclear Security Administration, "Highly Enriched Uranium Removed From Hungary" (Washington, D.C.: NNSA, 23 October 2008), available at http://nnsa.energy.gov/2189.htm as of 24 October 2008.

moval plans stretch to 2015, all but 217 kilograms of the planned removals are slated to be completed by the end of FY 2010.[57]

But policymakers assessing this effort should remember that GTRI's removal goal represents only a tiny part of the world's separated plutonium and HEU—or even of the world's civilian stockpiles. Unclassified estimates suggest that the global stockpile of HEU in 2007 was in the range of 1700 tons (though with wide uncertainty bounds), of which roughly 100 tons was in the civil sector, in the fuel cycles for either research reactors or Russia's nuclear icebreakers.[58] Much of that civilian HEU, however, is in the United States and Russia, and GTRI's mission does not include addressing material in these countries. There are roughly 19 tons of civilian HEU in other countries.[59] The global stockpile of separated plutonium is estimated to be roughly 500 tons, with growing civilian stocks probably exceeding the military stockpiles by 2007.[60] Hence GTRI's target for removing nuclear material represents less than a quarter of one percent of the global stockpile of nuclear material—though it represents roughly one-quarter of the stocks of civilian HEU outside the United States and Russia. In particular, GTRI has already returned roughly 90 percent of the eligible U.S.-origin HEU it ever plans to return; under current plans, more than four-fifths of U.S.-origin HEU abroad, amounting to over 12 tons of HEU, would not be removed as part of the program.[61] The amount of U.S.-origin HEU NNSA is expecting to return to the United States has actually shrunk, not grown, since the establishment of GTRI; this is contrary to the approach suggested in reports from the DOE Inspector General and the Government Accountability Office, which recommended that NNSA take additional steps to ensure that much more of this material was returned to the United States, including offering countries greater incentives to return it.[62] In response to those reports, however, DOE did shift the HEU fuel return effort to the GTRI program, to give it a greater nonproliferation focus, and extended the deadline for returning this HEU, to make it possible for more facilities to take advantage of the take-back offer. NNSA is also working on an environmental assessment that would make it legally possible to take back a

[57] U.S. Department of Energy, *FY 2009 NNSA Budget Request*, p. 531.

[58] International Panel on Fissile Materials, *Global Fissile Material 2007: Second Report of the International Panel on Fissile Materials* (Princeton, N.J.: Program on Science and Global Security, Princeton University, 2007; available at http://www.fissilematerials.org/ipfm/site_down/gfmr07.pdf as of 3 July 2008), pp. 8-22.

[59] Britain and France have declared that they have approximately 8 tons of civilian HEU between them. Roughly 10 tons exist in all non-nuclear-weapon states combined. International Panel on Fissile Materials, *Global Fissile Material 2007*, pp. 8-22, 119. Figures for China are highly uncertain, but the best available unclassified estimate suggests China may have roughly one ton of civilian HEU. 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/tableofcontents.html as of 21 July 2005).

[60] International Panel on Fissile Materials, *Global Fissile Material 2007*, pp. 8-22.

[61] This is the case even if one assumes that *all* the "gap" material GTRI plans to address is U.S.-origin HEU, which is not correct.

[62] 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-0637.pdf as of 2 August 2008); GAO, *DOE Needs to Consider Options to Accelerate the Return of Weapons-Usable Uranium*.

small quantities of material such as plutonium and non-U.S.-origin HEU.[63]

NNSA estimates that 98 percent of the U.S.-origin HEU that GTRI does not currently plan to address is in Australia, Canada, Japan, Switzerland, or the countries of Euratom (the nuclear agency of the European Union).[64] GTRI's plans do cover all but a small amount of the civil HEU in developing and transition countries other than Russia. GTRI documents argue that it is acceptable to leave some three-quarters of the material the program has identified where it is, as these materials "have an acceptable disposition path and/or they are in secure locations."[65] But as discussed in Chapter 2, just because countries are wealthy does not necessarily mean they invest in high levels of nuclear security; in Japan, for example, the lightly armed members of the national police now patrolling at nuclear facilities are not required by regulation and may be removed at any time, while in Belgium, there are no armed guards at all at nuclear sites, which rely on armed police forces some minutes away for protection.[66] Moreover, contrary to GTRI's argument, 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, and only a few countries have contracted to have their research reactor fuel reprocessed. Irradiated research reactor fuel continues to build up all over the world.

There are substantial uncertainties in GTRI's estimates of the amount of material in different categories. While recipients of U.S. nuclear material provide annual reports on their inventories, when nuclear material is exported to the countries of Euratom, 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 as to where that material is, leading to major uncertainties in tracking this material. NNSA'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.[67] NNSA is now preparing an in-depth assessment of the quantities and locations of the U.S.-origin HEU not covered under

[63] Data provided by NNSA, October 2008.

[64] Data provided by NNSA, October 2008.

[65] U.S. Department of Energy, *FY 2009 NNSA Budget Request*, p. 531.

[66] Interview with Japanese physical protection regulator, November 2006; interview with Belgian physical protection consultant, July 2008.

[67] NNSA 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 it is impossible to estimate its average burnup. Discussions with NNSA officials, July 2007. 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 percent 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 percent of the summed total has been destroyed by irradiation; and (c) one ton of HEU was in the 2 tons of HEU 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's current plans, attempting to clarify these uncertainties.[68]

HEU reactor conversions and shut-downs. Before the HEU can be removed 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.

As of the end of 2007, there were roughly 130 research reactors operating with HEU worldwide.[69] NNSA tracks a total of 207 HEU-fueled or formerly HEU-fueled reactors, including the approximately 130 research reactors still operating with HEU, the reactors GTRI and its predecessor programs have already succeeded in converting (or which shut down before they could be converted), and 15 reactors on nine Russian nuclear icebreakers.[70] 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); three still-operating reactors for producing plutonium or tritium and other isotopes (all in Russia);[71] an estimated 193 reactors for nuclear submarines and surface ships in four nuclear weapon states (though primarily in Russia and the United States); and a few reactors around the world that use roughly 40-50 kilograms of HEU per year for production of medical isotopes.[72] Thus the total number of reactors currently using either HEU fuel or HEU targets, plus the reactors already converted to LEU, is over 400.

GTRI hopes to convert 129 research reactors from HEU to LEU fuel—a 20 percent expansion over earlier plans.[73] Of these, 57 had been converted to LEU and five had shut down by the end of FY 2008, leaving 67 to go. Of the 67 remaining, GTRI believes that 39 could convert with LEU fuels that have already been developed, while 28 reactors cannot convert until higher-density LEU fuels now in development become available.[74] Many of the 28 reactors requiring high-density fuels are high-power reactors, so these 28 reactors account for a large fraction of the HEU consumed in civil research reactors every year.

With the additional funds it has received in recent years, GTRI has greatly accelerated the pace of HEU research reactor conversions to LEU. Eight of the targeted HEU-fueled research reactors either converted or shut down in FY 2007, and seven more are expected to do so in FY 2008.[75] GTRI hopes to complete the conversions it plans by the end of 2018—a schedule that is largely determined by the need to complete development of the high-density fuels, get commercial production of them underway, and then the time required to manufacture enough fuel for all the reac-

68 Data provided by NNSA, October 2008.

69 Reistad and Hustveit, "HEU Fuel Cycle Inventories."

70 Data provided by NNSA, July 2008.

71 Two additional Russian HEU-fueled plutonium production reactors shut down in the first half of 2008. See U.S. Department of Energy, National Nuclear Security Administration, "NNSA Announces the End of Plutonium Production in Seversk, Russia" (Washington, D.C.: NNSA, 5 June 2008, available at http://nnsa.energy.gov/news/2041.htm) as of 6 July 2008.

72 See discussion in Reistad and Hustveit, "HEU Fuel Cycle Inventories."

73 U.S. Department of Energy, National Nuclear Security Administration, *Strategic Plan: Reducing Nuclear and Radiological Threats Worldwide* (Washington, D.C.: DOE, 2007). See also U.S. Department of Energy, *FY 2009 NNSA Budget Request*, p. 531.

74 Data provided by NNSA, April 2008.

75 Data provided by NNSA, April 2008, and U.S. Department of Energy, *FY 2009 NNSA Budget Request*, p. 531.

tors that will convert to it and get those reactors converted. The schedule GTRI has laid is an ambitious one, and it does not appear likely that additional money or other steps could get this job done well before 2018.

Indeed, getting 129 research reactors converted by 2018 is likely to be very difficult to do. Many of the operators of these reactors have little interest in converting to LEU fuel; some are critical assemblies that essentially never consume their fuel, or other reactors that will have no need for new fuel for decades. Packages of incentives targeted to the needs of each particular facility and country (since some of the key decision-makers are typically at the site level, and some at the national level) are likely to be essential to meeting GTRI's objective. As just one of many possible examples, it is often the case that reactors that convert to LEU end up with a slight decrease in the flux of neutrons available for experiments—but a modest investment in neutron guides (which might be linked by donors to the reactor's agreement to convert to LEU) can increase neutron flux at the spot where the experiments are taking place by a factor of 10 or more, providing far *more* capability than was ever available before, rather than less.[76] Providing such targeted packages of incentives may require additional funds beyond those so far planned.

Even if GTRI can convert 129 research reactors, many more will be left. GTRI estimates that there are 63 HEU-fueled research reactors outside its scope, which it does not plan to attempt to convert, representing over 45 percent of all the research reactors still operating with HEU fuel—along with the 15 icebreaker reactors and the others discussed above. Of the 63 out-of-scope research reactors, 53 are in Russia, eight are reactors used for military purposes in the United States, and one each are military-purpose reactors in the United Kingdom and France.

Many of these difficult-to-convert reactors may no longer have essential roles to fill; for many, shutdown would be a more plausible option than conversion. Shutdown is also likely to be a cheaper and quicker option in many cases for reactors that *are* targeted for conversion. Roughly twice as many HEU-fueled research reactors have shut down as have converted since 1978, when conversion efforts began[77]—suggesting the potential power of strategies targeted on giving operators of little-used reactors (and the agencies which subsidize them) incentives to shut these facilities down. Indeed, at least two of the reactors on GTRI's list of reactors that are too difficult to attempt to convert have already shut down.[78] Unfortunately, neither the U.S. government nor any other government or international organization

[76] 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).

[77] Reistad and Hustveit, "HEU Fuel Cycle Inventories."; Reistad and Hustveit, "Appendix II."

[78] These are the Sandia Pulse Reactor (SPR)-II and SPR-III, both closed when all Category I and Category II nuclear material was removed from Sandia National Laboratories. In addition, GTRI has been contributing to the decommissioning of the Zero Power Physics Reactor (ZPPR) at the Idaho National Laboratory, which will allow the removal of several tons of HEU from that site. See, for example, U.S. Department of Energy, National Nuclear Security Administraiton, "First Phase of Nuclear Material Consolidation Complete" (Washington, D.C.: NNSA, 28 February 2008), available at http://nnsa.energy.gov/news/1800.htm as of 30 October 2008, and U.S. Department of Energy, National Nuclear Security Administration, "NNSA, Oregon State University and Washington State University Complete the Conversion of Two Research Reactors" (Washington, D.C.: NNSA, 2 October 2008), available at http://nnsa.energy.gov/news/2170.htm as of 30 October 2008.

today has a program focused on giving unneeded reactors incentives to shut down.

GTRI is also working to convert facilities that use HEU targets to produce medical isotopes. But here, too, the prospects are in doubt because the users of this HEU have little incentive to convert to LEU.[79] Approximately 95 percent 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.[80] Approximately 40-50 kilograms of HEU are irradiated for this purpose each year.[81] There are four large producers (including companies in Canada, the Netherlands, Belgium, and South Africa). Only MDS Nordion, a Canadian medical isotope firm, is continuing to receive regular supplies of HEU from the United States, while the others are continuing production with their existing stockpiles of HEU.[82] (Two smaller producers, in Argentina and Australia, already produce Mo-99 with LEU targets, and Indonesia is in the process of converting.[83]) 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, and have developed approaches that would make it possible to convert without substantially increasing costs or wastes.[84] 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.[85] In the spring of 2008, Canada abandoned efforts to complete the Maple reactors, which had been designed to produce Mo-99 using HEU, replacing

[79] For useful summaries, see Cristina Hansell, "Nuclear Medicine's Double Hazard: Imperiled Treatment and the Risk of Terrorism," *Nonproliferation Review,* Vol. 15, No. 2, July 2008, pp. 185-208, and Frank N. von Hippel and Laura H. Kahn, "Feasibility of Eliminating the Use of Highly Enriched Uranium in the Production of Medical Radioisotopes," *Science and Global Security* Vol. 14 (2006), pp. 151-162, available at http://www.princeton.edu/~globsec/publications/pdf/14_2-3_ percent20FvH_LK_Radio.pdf as of 2 August 2008. Alan Kuperman has been a particularly consistent and well-informed advocate for shifting medical isotope production to LEU. See, for example, Alan J. Kuperman, "the Global threat Reduction Initiative and Conversion of Isotope Production to LEU Targets," in *Proceedings of the 26th International Meeting on Reduced Enrichment in Research and Test Reactors,* Vienna, 7-12 November 2004, available at http://www.rertr.anl.gov/RERTR26/Abstracts/17-Kuperman.html as of 2 August 2008.

[80] 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).

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

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

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

[84] 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).

[85] 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."

the aging NRX reactor. The need to find some means of replacing NRX, which cannot keep running indefinitely—and the possibility that others in the United States may establish commercial Mo-99 production using LEU—may finally motivate MDS Nordion, which has been the most aggressive of the producers in resisting any shift toward LEU, to change its position and pursue LEU production options, but this remains to be seen.

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

Figure 3.3 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 remains a great deal of white space on this chart—white space representing potential nuclear bomb material not yet protected from the kinds of capabilities terrorists and thieves have shown they can muster. There is an enormous amount that remains to be done. There is still a dangerous gap between the urgency of the threat and the scope and pace of the U.S. and international response.

Improved Indicators 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 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.[86] 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 estimate overall risk in this way, 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.[87]

The priority the recipient state's government assigns to nuclear security and accounting. This could be assessed on the basis of 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 they were followed, would result in effective 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.[88] To guide its regulatory development work with Russia, NNSA has developed a tool that essentially lists all of the most important aspects of physical protection, material control, and material accounting that should be included in regulations—but that does not represent a method for assessing the actual effectiveness of a regulatory program.[89] Surveys that probe the experience of managers and other personnel at nuclear sites 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

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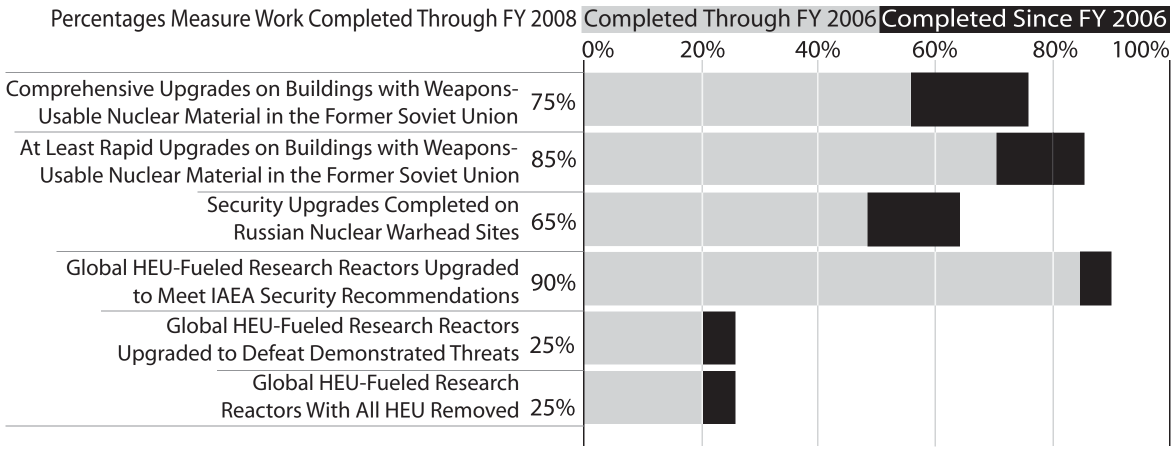
[86] NNSA uses this metric to track the performance of its own nuclear security program. See, for example, "Detailed Information on the National Nuclear Security Administration: Safeguards and Security Assessment" (Washington, D.C.: Office of Management and Budget, 2008, available at http://www.whitehouse.gov/omb/expectmore/detail/10000126.2004.html) as of 2 August 2008.

[87] 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.

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

[89] 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).

Figure 3.3: Progress of U.S.-Funded Programs to Secure Nuclear Stockpiles



Source: Author's estimates.

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.[90] NNSA and Rosatom have jointly developed a methodology for assessing security culture that has been applied at two U.S. and two Russian facilities on a pilot basis, but little information is publicly available about this tool, or the results of these initial assessments.[91]

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

[90] 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 9 July 2007).

[91] Interview with DOE laboratory expert, February 2008.

by expert reviews, given the difficulty of quantification.

NNSA's MPC&A program is now putting a substantial focus on progress toward strong security cultures and long-term sustainability. 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.

4 U.S. BUDGETS FOR IMPROVING CONTROLS OVER NUCLEAR WEAPONS, MATERIALS, AND EXPERTISE OVERSEAS

In Washington, it is often said that budgets are policy. The fact that the entire budget for all programs to prevent nuclear terrorism comes to less than one-quarter of one percent of the defense budget makes a clear statement about whether this effort is really a top priority of the U.S. government—and makes clear that the U.S. government could easily afford to do more, if more effort is needed. See Figure 4.1.

But in the case of preventing nuclear terrorism, policy is much more than budgets. Money is necessary but by no means sufficient. Most programs intended to reduce the risk of nuclear terrorism are constrained more by limited cooperation (resulting from secrecy, complacency about the threat, concerns over national sovereignty, and bureaucratic impediments) than they are by limited budgets. Sustained high-level leadership focused on overcoming the obstacles to cooperation would do more to increase the chances of success than larger budgets would. But in some cases, programs could move more quickly to seize risk reduction opportunities that already exist if their budgets were increased—and in still more cases, more money would be needed to implement a faster and broader effort if the other obstacles could be overcome.

As described in detail in the previous chapter, programs to reduce the risk of nuclear terrorism are making substantial progress, but there will still be much more to do when a new team takes office in January 2009. While many of the programs in Russia are nearing completion, and their budgets will decline, efforts elsewhere around the world must expand to address the global threat.

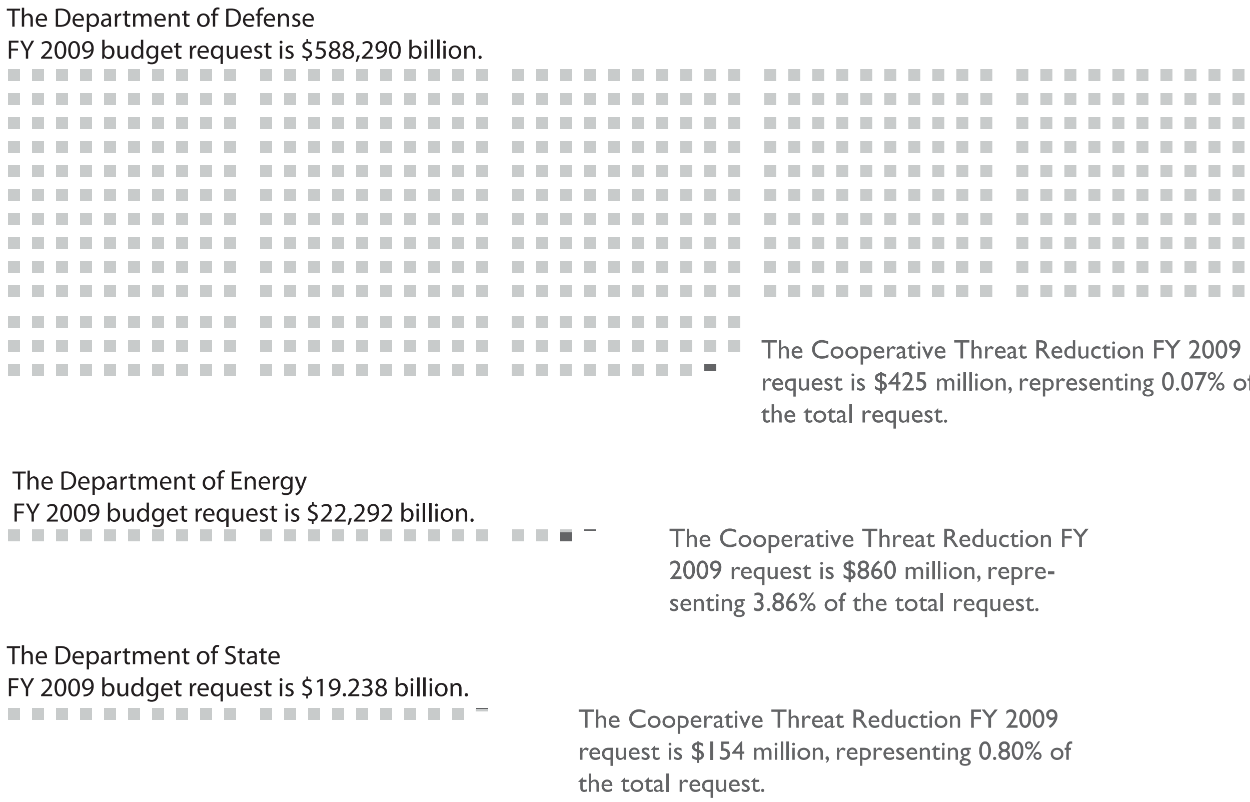
In September 2008, Congress passed a continuing resolution through March 6, 2009 that simply allows most government programs to spend at the same rate that they were spending in fiscal year (FY) 2008, which ended on September 30. The legislation did, however, include a full year's appropriation for the Department of Defense (DOD). The new Congress will need to pass a budget for the remainder of FY 2009; working with the new president, Congress should take action to ensure that sufficient funds are available to reduce nuclear terrorism risks as quickly as that can practicably be done.

Threat Reduction Budgets: An Overview

For FY 2009, President Bush requested a total of $1.083 billion for all programs to improve controls over nuclear weapons, materials, and expertise overseas, an 18 percent reduction from the funding Congress appropriated in FY 2008.[1]

[1] For precise figures and references, see Table 4.1. This figure includes U.S.-funded programs to improve controls over nuclear weapons, nuclear materials, and expertise in foreign countries; it does not include other threat reduction programs, or programs for security or disposition of U.S. nuclear stockpiles, or interdicting nuclear smuggling at the U.S. borders or within the United States (the latter activities being within the budget of the Department of Homeland Security). For a discussion of what programs are included and why, 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, 2004; available at http://www.nti.org/e_research/cnwm/overview/funding.asp as of 15 March 2005). For a broader discussion

Figure 4.1: Components of Departments of Energy, State, and Defense FY 2009 Budget Requests Devoted to Cooperative Threat Reduction Programs
(each full box represents $1 billion)



Source: Department budget requests from Table 5.2 in U.S. Office of Management and Budget, "Historical Tables," Fiscal Year 2009 Budget of the United States Government (Washington, D.C.: OMB, 2008; available at http://www.whitehouse.gov/omb/budget/fy2009/pdf/hist.pdf as of 11 November 2008). Department totals include OMB estimates of supplemental funding requests for FY 2009.

See Table 4.1. The appropriation Congress provided in FY 2008 was 34 percent more than the administration had requested—in part as a result of Congress rescinding prior-year funding for plutonium disposition and then reassigning those funds as FY 2008 appropriations. While a cut from last year's appropriation, the request is 10 percent higher than the FY 2008 request.

of funding and policy for NNSA's nonproliferation programs, covering programs in addition to those focused on improving controls on nuclear weapons, materials, and expertse overseas, see Matthew Bunn, "Next Steps to Strengthen the National Nuclear Security Administration's Efforts to Prevent Nuclear Proliferation," testimony to the Subcommittee on Energy and Water, Committee on Appropriations, U.S. Senate, 30 April 2008. For a detailed analysis of the history of these budgets, see Anthony Wier and Matthew Bunn, *Funding for U.S. Efforts to Improve Controls over Nuclear Weapons, Materials, and Expertise Overseas: Recent Development and Trends* (Cambridge, Mass.: Project on Managing the Atom, Harvard University, 2007; available at http://www.nti.org/securingthebomb as of 9 June 2008). For complementary analyses of the budget requests for FY 2009, see Jennifer Lacey, "Analysis of the State Department's FY 2009 Nonproliferation Budget Request" (Washington, D.C.: Partnership for Global Security, 2 April 2008; Raphael della Ratta, "Analysis of the DOD FY2009 Cooperative Threat Reduction Budget Request" (Washington, D.C.: Partnership for Global Security, 26 March 2008); and "Analysis of the DOE's FY2009 Nonproliferation Budget Request" (Washington, D.C.: Partnership for Global Security, 20 March 2008).

Of the $241 million cut from the FY 2008 appropriation for these programs, $195 million, some 80 percent of the total, comes from just two programs—Material Protection, Control, and Accounting and Second Line of Defense. Both of these programs received very large budget increases in FY 2008, in effect receiving some of the money in FY 2008 that the administration would otherwise have requested for FY 2009. In addition, some programs (such as Nuclear Warhead Security and Elimination of Weapons-Grade Plutonium Production) have declining budgets because their work is nearing completion. It is striking, however, that with the exception of the Global Threat Reduction Initiative (GTRI), the administration does not appear to be expanding other efforts or launching new ones as some of the efforts in the former Soviet Union near the finish line.

Total requested funding for all cooperative threat reduction programs is $1.439 billion, a 15 percent cut from the FY 2008 appropriation. See Table 4.2. Virtually all of this reduction was in programs at the National Nuclear Security Administration (NNSA) of the U.S. Department of Energy (DOE), which suffered a 24 percent cut in its threat reduction programs. NNSA, however, remains by far the largest sponsor of threat reduction efforts, with programs more than twice as large as those implemented by DOD. All of the reduction in total threat reduction funding was focused on the programs to improve controls over nuclear weapons, materials, and expertise; funding for threat reduction programs focused on chemical and biological weapons and dismantlement of missiles and launchers, submarines, and bombers generally remained flat or increased slightly.

Securing Nuclear Warheads and Materials

The requested funding for FY 2009 for programs focused on improving security and accounting for nuclear weapons and materials is $506 million. If approved, this would be a $133 million cut from the FY 2008 level—largely because some programs are close to finishing their upgrade work, or received very large increases in the FY 2008 appropriation. There are, nevertheless, opportunities for additional progress if more money were allocated. Some highlights:

- **MPC&A.** President Bush's proposed budget would cut NNSA's MPC&A program by $141 million from the FY 2008 appropriation, to $217 million. Judged from the effort's $406 million peak in FY 2007, the decline is even more substantial. The proposed cutback would come primarily in work on upgrading security at nuclear warhead sites (which is almost complete), at buildings in the Rosatom weapons complex (where there is still substantial work to be done, including some post-Bratislava work not scheduled to be completed by the end of 2008), and in work at civilian sites (the Russian portion of which is nearing completion, though this line also funds work in China, Pakistan, and India). Congress gave the MPC&A effort $76 million more than the requested budget in FY 2008, and that boost came half-way through the fiscal year, making it almost inevitable that some of it would carry over into FY 2009.[2] But construction costs in Russia have shot up since the administration prepared its budget request; helping Russian sites to prepare to sustain high levels

[2] The budget appropriated by Congress was $106 million more than the original FY2008 request, but the administration also made a $30 million supplemental request for the MPC&A program.

Table 4.1. U.S. Appropriations to Improve Controls on Nuclear Weapons, Materials and Expertise
(Current Dollars, in Millions)

Goal/Program		FY08 Request	FY08 Estimated	Change from Request		FY09 Request	Change from FY08	
Total, Improving Controls on Nuclear Weapons, Material, and Expertise		**$986**	**$1,324**	**+$339**	**34%**	**+$1,083**	**-$241**	**-18%**
Securing Nuclear Warheads and Materials		488	639	+151	+31%	506	-133	-21%
Material Protection, Control, & Accounting (excluding SLD)	Energy	282	358	+76	+27%	217	-141	-39%
Nuclear Weapons Storage Security - Russia	Defense	23	46	+23	+98%	24	-21	-47%
Global Threat Reduction Initiative	Energy	140	193	+53	+38%	220	+26	+14%
Nuclear Weapons Transportation Security - Russia	Defense	38	38	0	-1%	41	+3	+8%
International Nuclear Security	Energy	5	5	0	-2%	5	0	-7%
Interdicting Nuclear Smuggling		209	385	+176	+84%	315	-70	-18%
Second Line of Defense (part of MPC&A budget line)	Energy	119	267	+148	+124%	213	-54	-20%
Export Control and Related Border Security Assistance	State	41	46	+5	+11%	41	-4	-9%
WMD Proliferation Prevention	Defense	38	58	+20	+53%	50	-8	-13%
International Counterproliferation [1]	Defense	11	14	+3	+30%	10	-4	+27%
Stabilizing Employment for Nuclear Personnel		79	92	+14	+18%	91	-1	-1%
Global Threat Reduction Program [2]	State	54	57	+3	+6%	64	+7	+12%
Global Initiatives for Proliferation Prevention	Energy	20	31	+11	+55%	24	-7	-23%
Civilian Research and Development Foundation [3]	State	5	5	0	0	4	-1	-22%
Monitoring Stockpiles and Reductions		28	28	0	+1%	29	+1	+2%
HEU Transparency Implementation	Energy	14	14	0	+3%	15	0	+3%
Warhead and Fissile Material Transparency	Energy	14	14	0	-2%	14	0	+2%
Ending Further Production		182	180	-2	-1%	141	-39	-21%
Elimination of Weapons Grade Plutonium Production	Energy	182	180	-2	-1%	141	-39	-21%
Reducing Excess Stockpiles		0	0	0		1	+1	
Russian Plutonium Disposition	Energy	0	0	0		1	+1	

Notes
Values may not add due to rounding.

Source: "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, 2008; available at http://www.nti.org/e_research/cnwm/overview/funding.asp as of 5 June 2008), updated by Matthew Bunn and James Platte, June 2008.

Except where noted, figures are taken from the following budget documents: U.S. Department of Defense, Fiscal Year (FY) 2009 Budget Estimates: Former Soviet Union Threat Reduction (Washington, D.C.: U.S. Department of Defense, 2008; available at http://www.defenselink.mil/comptroller/defbudget/fy2009/budget_justification/pdfs/01_Operation_and_Maintenance/O_M_VOL_1_PARTS/x%200134%20CTR%20FY%2009%20PB%20OP-5.pdf as of 5 June 2008; U.S. Department of Energy, FY 2009 Congressional Budget Request: National Nuclear Security Administration, vol. 1, DOE/CF-024 (Washington, D.C.: DOE, 2008; available at http://nnsa.energy.gov/management/documents/FY09_Budget_Request.pdf as of 5 June 2008); U.S. Department of State, FY 2009 International Affairs (Function 150) Congressional Budget Justification (Washington, D.C.: U.S. Department of State, 2007; available at http://www.state.gov/f/releases/iab/fy2009cbj/ as of 5 June 2008); and U.S. Office of Management and Budget, Budget of the United States Government: Fiscal Year 2009 (Washington, D.C.: OMB, 2008; available at http://www.whitehouse.gov/omb/budget/fy2009/ as of 5 June 2008).

1. U.S. Department of Defense, Fiscal Year (FY) 2009 Budget Estimates: Defense Threat Reduction Agency (Washington, D.C.: U.S. Department of Defense, 2008), p. 484.
2. A small portion of these funds are spent on programs to interdict nuclear smuggling, particularly the Nuclear Smuggling Outreach Initiative.
3. Estimated based on interview with CRDF official, May 2008. The figures here include only funds provided to CRDF for its own programs, not funds from other programs listed here which use CRDF as a facility for spending money on their programs.

of security is proving more expensive than expected; and new understandings have opened new opportunities for nuclear security cooperation in both Russia and South Asia.[3] All told, an increase of $60-$70 million over the requested budget—restoring roughly half of the proposed cut from the FY 2008 level—appears to be needed to seize the opportunities that are already available.

[3] Interviews with DOE officials, May 2008.

Table 4.2. U.S. Appropriations for Cooperative Threat Reduction, by Department
(Current Dollars, in Millions)

Department	FY08 Request	FY08 Estimated	Change from Request		FY09 Request	Change from FY08	
Total, Cooperative Threat Reduction	$1,293	$1,652	+$359	+28%	$1,439	-$213	-15%
Department of Energy	786	1,071	+285	+36%	860	-211	-24%
Department of Defense	359	440	+81	+23%	425	-16	-4%
Department of State	148	141	-7	-5%	154	+13	+8%

Notes
Values may not add due to rounding.

Source: "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, 2008; available at http://www.nti.org/e_research/cnwm/overview/funding.asp as of 5 June 2008), updated by Matthew Bunn and James Platte, June 2008.

- **GTRI.** By contrast, although Congress boosted GTRI's budget by $53 million over the $140 million request in FY 2008, the FY 2009 request proposes a further $26 million increase, to $220 million. Launched in 2004 and focused on global threats rather than primarily zeroing in on threats in the former Soviet Union, GTRI is still expanding, rather than nearing the end of its work. Despite the modest requested budget increase, substantially more funds would be required to seize all the opportunities available to GTRI. There are now 45 HEU-fueled research reactors that could convert to proliferation-resistant low-enriched uranium (LEU) with LEU fuels already available; GTRI has already accelerated the pace of these conversions, but with more money, these reactors could be converted faster. There will also be a need to build a fabrication plant for the higher-density LEU fuels now in development, in order to convert additional reactors, and GTRI will likely have to play a role in that—either by paying to build the plant or by guaranteeing fabrication contracts to give private firms sufficient incentives to pay for building their own facilities. Additional funds could also accelerate the pace of removing nuclear material from vulnerable sites around the world (in part because here, too, prices are escalating). More money is also needed to secure radiological sources and research reactors around the world—including in the United States, where upgrades are needed for some 1,800 locations with sources of 1,000 curies or more, and for the nation's 32 domestic research reactors, both of which have now been included in GTRI's scope.[4] Moreover, GTRI is so far planning to return only a small fraction of the U.S.-origin HEU abroad; while most of the remainder is in developed countries, in many cases there is good reason to bring this material back as well, and more funds would be required to give these facilities incentives to give up their HEU. Finally, NNSA does not yet have a program focused on giving underutilized HEU-fueled reactors incentives to shut down—in many cases likely to be a quicker and easier approach than conversion. All told, an increase of $200 million or more would be needed for GTRI to more forward as rapidly as possible in reducing these risks—though managing such a large single-year increase would pose a challenge.[5]

[4] Interviews with DOE officials, May 2008.

[5] This does not include the potential cost of packaging and removing plutonium and plutonium-bearing spent fuel from North Korea, if an

- **Warhead security and warhead transport at DOD.** DOD's Nuclear Weapons Security program would be cut by $21 million (47 percent) in the proposed FY 2009 budget, because it will largely finish its upgrade work with FY 2008 funds. The FY 2009 funds are requested primarily for sustainability and training activities. By contrast, DOD's Nuclear Weapons Transportation Security Program would receive roughly level funding, continuing to finance roughly four shipments a month of Russian nuclear warheads to dismantlement or secure central storage locations. This is planned to continue through 2012.

Interdicting Nuclear Smuggling

Congress appropriated $176 million more than the Bush administration had requested for programs focused on interdicting nuclear smuggling in FY 2008, an 84 percent increase.[6] In the FY 2009 request, the Bush administration went along with most of that budget boost, with a total request of $315 million for these programs—18 percent less than Congress' FY 2008 level, but 50 percent more than the administration had asked for in FY 2008. The increased funding is intended primarily to make it possible to install radiation detectors at key border crossings and ports around the world at a faster pace.

In addition, the administration requested $190.7 million in the budget for the Department of Homeland Security (DHS) for the purchase of radiation detection systems for use within the United States, a 47 percent increase over the previous year. Also at DHS, the administration asked for $149.5 million for "International Cargo Screening," including activities in support of the Container Security Initiative and the Secure Freight Initiative.[7] (Actual radiation scanning equipment to detect nuclear cargoes for these initiatives, however, is provided by NNSA's Second Line of Defense program.)[8]

Some highlights:

- **Second Line of Defense.** Second Line of Defense received almost all of the huge Congressional budget boost for programs focused on interdicting nuclear smuggling in FY 2008. The proposed FY 2009 budget would cut the Second Line of Defense program by $54 million (20 percent) from the FY 2008 appropriation to $213 million. This is still 79 percent more than the administration's FY 2008 request, however. Nevertheless, the Second Line of Defense program has been successful in getting additional countries to agree to cooperate, and to take advantage of all the opportunities for cooperation with key countries that it now has before it would likely require $50-$60 million beyond the budget request.[9]

agreement to take those steps is reached. That substantial cost would likely have to be funded through a supplemental request.

[6] This figure does not include significant, but classified, resources from the intelligence community devoted to tracking and interdicting nuclear smuggling. In addition, it does not include the small portion of the State Department's Global Threat Reduction Program that is devoted to efforts to interdict nuclear smuggling, such as the Nuclear Smuggling Outreach Initiative; because State does not routinely break out how much is spent for which purpose in this program in public documents, the entire program is listed here under its principal scientist-redirection mission.

[7] For a useful summary of the DHS request as it relates to these topics, see Jennifer Lacey, "Analysis of the Department of Homeland Security's Fiscal Year 2009 Budget Request for Nuclear and Biological Security Activities" (Washington, D.C.: Partnership for Global Security, 1 May 2008).

[8] Since the DHS funds are either for deployments within the United States or for the broad elements of cargo security going beyond nuclear detection, they are not included in Table 4.1, though they clearly contribute to reducing the risk of nuclear terrorism.

[9] Interview with DOE official, May 2006.

Stabilizing Employment for Nuclear Personnel

Programs focused on redirecting weapons scientists to civilian work have taken on new missions in recent years, going beyond the former Soviet Union to new areas where former weapons scientists may pose proliferation risks, such as Iraq and Libya. At the same time, these efforts clearly need to be reformed to match today's threats. The dramatically changed Russian economy creates a very different threat environment; for many former weapons scientists, the risk of desperation-driven proliferation that motivated the U.S. government to establish these programs is much less than it was before. Moreover, the experience of the A.Q. Khan network suggests that dramatic leakage of proliferation-sensitive expertise may come from well-to-do experts motivated by ideology and greed, and not only from desperate, underemployed experts.

In addition, after 9/11, U.S. concerns have changed, with a much greater focus on nuclear or biological terrorism, as opposed to only proliferation by states. [10] For a terrorist group, a physicist skilled in modeling the most advanced weapons designs—the kind of person who has often been the focus of these programs in the past—may be much less interesting than a machinist experienced in making bomb parts from HEU metal, or a guard in a position to let thieves into a building undetected. Experts who are no longer employed by weapons institutes, but whose pensions may be inadequate or whose private ventures may have failed, could pose particularly high risks, but they are not addressed by current programs focused on redirecting weapons expertise.

The U.S. government needs to find ways to address all of the highest-priority risks—but is not likely to have either the access or the resources to do everything itself. The solution is likely to require working in partnership with Russia and other countries, to get them to do most of what needs to be done.

For FY 2009, President Bush proposed a budget of $91 million for programs to stablize employment for nuclear personnel, roughly level with the previous year.[11] Some highlights:

- **Global Threat Reduction Program.** Alone among the scientist-redirection programs, State's Global Threat Reduction Program would receive a budget increase in the proposed FY 2009 budget to $64 million. Because of the changing picture in Russia, however, the fraction of this program

[10] For a useful discussion of this changed threat environment and its implications, see Laura Holgate, testimony to the Subcommittee on Prevention of Nuclear and Biological Attack, Committee on Homeland Security, U.S. House of Representatives, 26 May 2005 available at http://www.nti.org/c_press/c4_testimony.html as of 11 November 2008. See also John V. Parachini and David E. Mosher, *Diversion of NBC Weapons Expertise from the FSU: Understanding an Evolving Problem* (Santa Monica, Cal.: RAND, 2005). For additional suggestions for new approaches, 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 28 March 2008), pp. 141-146.

[11] This is a substantial overstatement of the amount actually devoted to *nuclear* scientists, as opposed to chemical, biological, or missile experts because of the difficulty of determining how much is being spent for each category of expert in a timely way each year, in these budget estimates, we simply include the entire budgets for the scientist-redirection programs, unless they are specifically identified as non-nuclear efforts, as is the case with the Biological Threat Reduction program sponsored by the Department of Defense. Actual funding for nuclear experts is certainly less than half of this total, and may be less than one-third.

devoted to the former Soviet Union has greatly decreased. Today, only a minority of these funds are spent in the former Soviet Union, and only a fraction of the total is spent on nuclear scientists, as opposed to biological, chemical, or missile experts.[12] (State's contribution to the Civilian Research and Development Foundation (CRDF) has also been steadily declining.)

- **Global Initiative for Proliferation Prevention.** The proposed FY 2009 budget would cut NNSA's redirection program, now known as Global Initiatives for Proliferation Prevention (GIPP), by 23 percent from the FY 2008 appropriation, to $24 million. GIPP has come under intense criticism in recent years, from analysts who argued it was no longer needed, given improving economic conditions in Russia; from Congressional investigators who pointed out that a significant portion of the long-term jobs the program claims to have created have gone to people who never were weapons experts;[13] and from members of Congress who have complained about the program funding projects at institutes which also have personnel working on Iran's safeguarded nuclear power reactor.[14] Despite the recent improvements in the Russian economy, however, a strong case can be made that reformed NNSA scientist-redirection programs, which help integrate former Soviet weapon scientists into the world technical community with its nonproliferation norms, maintain an ongoing dialogue with institutes that will be central to the future of Russia's weapons programs, and provide access to technologies that benefit U.S. industry, continue to offer benefits to U.S. national interests that are worth the modest investments the U.S. government makes in them. The fact that some institutes that have received NNSA funds also have some experts who have worked on a safeguarded power reactor in Iran does not in any way mean that NNSA programs have somehow contributed to Iran's nuclear program. Moreover, while a substantial fraction of the long-term jobs these programs have created have gone to people who are not weapons scientists, that is hardly a surprise. It is hard to think of a new business in the United States or elsewhere that has former weapons scientists for 100 percent, or even 80 percent, of its employees. To maintain the momentum of this effort, a budget of roughly $30 million (comparable to the fiscal 2008 appropriation) would be appropriate, combined with direction to carry out an in-depth analysis of what the most urgent risks of proliferation of weapons expertise are, and how they might best be addressed.

Monitoring Nuclear Stockpiles and Reductions

For FY 2009, the administration proposed essentially flat funding of $29 million for programs focused on monitoring nuclear stockpiles and reductions—$15 million for ongoing implementation of transparency measures for the U.S.-Russian HEU Purchase Agreement, and $14 million for Dismantlement and Transparency program (formerly known as Warhead and Fissile Materials Transparency), which focuses on developing key transparency

[12] Interview with State Department official, May 2006.

[13] See U.S. Government Accountability Office, *Nuclear Nonproliferation: DOE's Program to Assist Weapons Scientists in Russia and Other Countries Needs to be Reassessed* (Washington, D.C.: December 2007).

[14] Matthew Wald, "U.S.-Backed Russian Institutes Help Iran Build Reactor," *New York Times,* 7 February 2008 available at http://www.nytimes.com/2008/02/07/washington/07nuke.html as of 11 November 2008.

and counter-terrorism technologies jointly with Russian experts and supporting a range of negotiations involving transparency or verification for nuclear warheads and materials. If a transparency agreement is reached for the Mayak Fissile Material Storage Facility, the Department of Defense intends to reprogram funds to support transparency implementation.[15]

Ending Further Production

For FY 2009, President Bush requested $141 million for Eliminating Weapons-Grade Plutonium Production, the one program substantially focused on ending additional production of fissile material. (Negotiation of a fissile cutoff treaty is also focused on that objective, but does not have a separate budget line-item.) This represents a 21 percent cut from the FY 2008 appropriation, largely because the program is finishing its work. The program has already succeeded in helping Russia shut down two of the three remaining plutonium production reactors, each of which were producing of the order of 400 kilograms of plutonium per year. The last reactor, at Zheleznogorsk, is expected to shut down in 2010.

Reducing Excess Stockpiles

The Bush administration did not ask for any funds for reducing Russia's stockpiles of nuclear weapons and weapons-usable materials in FY 2009. Much to the surprise of many, the United States has never paid for the actual dismantlement of nuclear weapons in Russia. (The ongoing HEU Purchase Agreement, under which Russia blends HEU from weapons to LEU and sells the LEU to the United States, gives Russia a financial incentive to dismantle weapons and destroy HEU, and DOD's Nuclear Weapons Transportation Security program helps transport warheads to dismantlement sites, but neither of these involve direct support for the actual dismantlement of nuclear weapons.)

Similarly, the HEU Purchase Agreement is implemented commercially, and does not require U.S. government financing (except for the associated transparency measures, noted above). In the FY 2008 budget, Congress rescinded all unspent prior-year funds for supporting Russian plutonium disposition, and the Bush administration did not request any funds for this purpose this year.

U.S. Plutonium Disposition

In FY 2008, Congress also slashed the requested budget for U.S. plutonium disposition, rescinded half of the prior-year balances remaining for construction of a plutonium-uranium mixed oxide (MOX) fuel fabrication plant, and moved the program to the Office of Nuclear Energy. For FY 2009, the administration requested $487 million for the effort to build a plutonium-uranium mixed oxide (MOX) fuel fabrication plant in the United States for disposition of excess plutonium, in the "Other Defense Activities" account.[16] This represents a 75 percent increase over the $279 million FY 2008 appropriation. In addition, the administration is requesting $26.9 million for construction of the Pit Disassembly and Conversion Facility (PDCF), for dismantling plutonium weapons components, and $40 million for construction of the Waste Solidification Building, to support the MOX plant

[15] U.S. Department of Defense, *Cooperative Threat Reduction Annual Report to Congress: Fiscal Year 2009* (Washington, D.C.: DOD, 2008; available at http://www.dtra.mil/documents/oe/ctr/FY09 percent20CTR percent20Annual percent20Report percent20to percent20Congress.pdf as of 9 June 2008), p. 15.

[16] U.S. Department of Energy, *FY 2009 Congressional Budget Request: Other Defense Activities*, vol. 2, DOE/CF-025 (Washington, D.C.: DOE, 2008; available at http://www.cfo.doe.gov/budget/09budget/Content/Volumes/Volume2.pdf as of 9 June 2008), p. 105.

and the PDCF. All of these facilities are to be built at the Savannah River Site in South Carolina.

The cost of the U.S. MOX program has skyrocketed over the years. DOE's latest published estimates indicate a life-cycle cost for the MOX facility of some $7.2 billion (not counting the substantial cost of the pit disas-

Analysis in Support of Preventing Nuclear Terrorism

In an ideal world, every dollar spent to prevent nuclear terrorism would go where it could do the most good in reducing the risk. The reality, however, is that no methodology is available that would make possible an accurate calculation of the marginal risk-reduction benefit of additional spending in one area rather than another: the uncertainties in the risk of nuclear terrorism, and the effectiveness of different means of addressing it, are simply too great. Unfortunately, little effort is devoted to even attempting cross-program and cross-department analyses of where additional funds could do the most good; the many relevant agencies of the U.S. government, each with their own perspectives and approaches, are not well structured to do that kind of strategic, interdisciplinary analysis. Instead, budgets are allocated in the usual political rough-and-tumble of decision-making, in which the political popularity of different efforts, the attitudes of different authorization and appropriation committees, the interests of particular political and bureaucratic actors, and institutional momentum all play prominent roles.

Indeed, while this paper examines the cumulative resources available for these programs throughout the government, no one in the U.S. government considers these budgets as a whole at any point in the annual budget process. The Departments of Energy, Defense, and State each follow separate tracks toward their final budget numbers. Budget tradeoffs are generally made within each department, working with different examiners at the Office of Management and Budget (OMB). Each budget is then voted on by a separate appropriations subcommittee in the House and the Senate.

Fortunately, in this process, substantial resources have, in the end, been allocated to the highest-leverage opportunities for reducing the risk—such as programs to install improved security measures at vulnerable facilities, or to remove nuclear material entirely from them. More in-depth analysis of costs and benefits, however, would help reallocate resources more productively. If, in fact, it would not be difficult to smuggle nuclear material into the United States, then it does not make a great deal of sense to invest large sums to protect nuclear materials at DOE to a far higher standard than is applied to similar materials in other countries; the threat to U.S. interests that would be posed by theft of nuclear bomb material in another country is almost as large as the threat posed by a theft within the United States would be. And it makes no sense for different facilities *within the United States* to be protected against dramatically different threats when they have identical nuclear materials, as is the case today with DOE facilities and facilities with large quantities of HEU that are regulated by the Nuclear Regulatory Commission (NRC); either the nuclear security standards at DOE, which are far more stringent than those set by the NRC, are too high, or those at the NRC are too low, but they cannot both be right—and hundreds of millions of dollars are being spent every year to meet the stringent DOE standards. Similarly, it is not at all obvious that in-depth analysis could justify the billions being invested in radiation scanning of cargo containers when so little is being invested to stop nuclear material coming in yachts or backpacks.

In short, additional investment in analyzing what should be done and how best to do it could increase the effectiveness of efforts to prevent nuclear terrorism, and potentially save money as well. Neither the U.S. government nor the national laboratories—who have their own institutional interests in particular programs and approaches—are well-suited to do this kind of analysis, though each have their roles to play. The U.S. Department of Homeland Security has invested in establishing several "centers of excellence" for university-based analysis of particular categories of homeland security problems, along with other programs focused on bringing in academic expertise to contribute to improving homeland security. A strong case can be made that the agencies carrying out threat reduction programs should do the same, setting aside a small portion of the threat reduction budget—perhaps 1-2 percent of total spending—to finance non-government analyses of effective approaches to reducing proliferation risks. Such programs should also support training of the next generation of nonproliferation experts.

In addition, every program can benefit from independent perspectives. Each major program focused on reducing the risk of nuclear proliferation and terrorism should have a standing advisory group of outside experts, with full access to information about the program's activities, regularly reviewing its efforts and suggesting ideas for improvement.

Finally, high-quality information is critical to improving the effectiveness of these programs. Each of these programs should undertake a focused effort to identify what information would be most useful to strengthening their efforts and to map out ways that this information might be acquired. At the same time, it is critical that adequate resources be provided for intelligence support for reducing the threat of nuclear terrorism. As discussed in the previous chapter, the Bush administration has taken a major step forward in this area, with the establishment of the Nuclear Material Information Program (NMIP), centered at DOE's Office of Intelligence and Counterintelligence, intended to compile key information on nuclear stockpiles, their security, and the threats to them around the world. Resources devoted to nuclear theft, nuclear smuggling, and nuclear terrorism have been substantially increased elsewhere in the U.S. government as well. But it is also critical to maintain and build on the critical capabilities at the national laboratories, such as Z Division at Lawrence Livermore National Laboratory; these national laboratory capabilities have suffered substantial budget cutbacks in recent years, though details are not publicly available.

sembly and conversion facility). DOE has never adequately explained why this facility is costing many times what comparable facilities in Europe with more capability cost to build. Even once the expected $2 billion in expected revenue from MOX sales is subtracted, this still comes to over $120 million per ton of excess plutonium.[17]

[17] Total project cost for construction is $4.8 billion. Operations and maintenance is estimated at $2.4 billion. See U.S. Department of Energy, *FY 2009 DOE Other Defense Activities*, pp. 140-141. The per-ton calculation

Something has to be done with this plutonium, but it would be surprising if no effective approach could be found that would manage this material securely for less than $120 million per ton. If judged solely as a nuclear energy initiative, building such a plant would certainly not be worthwhile; it would demonstrate nothing except the ability to replicate in the United States an expensive fuel cycle approach with significant proliferation risks that is already routinely done in Europe, and even if a demonstration fast reactor were built for GNEP in the near term (which seems both unlikely and unwise), the initial core could be fabricated elsewhere at lower cost.

Unfortunately, lower-cost alternatives are not yet sufficiently mature that the MOX effort could be canceled with high confidence that something better would be available. Given that reality, Congress should consider approving funding to proceed with the MOX plant for this year, while simultaneously directing DOE to carry out an in-depth study of potentially lower-cost alternatives—including some alternatives that were not fully explored in recent options studies. In particular, Congress should provide funding for DOE to restart development of plutonium immobilization technology, and direct DOE to outline the lowest-cost practicable immobilization option for the entire excess plutonium stockpile; Congress should also direct DOE to include, in its options assessment, the option of transporting the excess plutonium to Europe for fabrication and irradiation in existing facilities there. If, for example, the French were willing to take the U.S. excess plutonium and use it in their existing MOX programs for a one-time payment of $1 billion, the U.S. government would have saved billions compared to other approaches; if not, that would certainly make clear that even with high uranium prices, plutonium is a costly liability, not an asset.[18]

On the Russian side, critics have raised legitimate concerns about using excess plutonium in the BN-800 fast-neutron reactor, since it creates roughly as much plutonium as it burns. While NNSA is working with Russia to modify the reactor from a plutonium "breeder" to a plutonium "burner," consuming more plutonium than it produces, this is largely a distinction without a difference, as the baseline design for the BN-800 produces only slightly more plutonium than it consumes, and the revised design produces only slightly less. More important is the fact that under the 2000 Plutonium Management and Disposition Agreement, spent fuel from plutonium disposition will not be reprocessed until decades from now, when disposition of all the plutonium covered by the agreement has been completed. Thus, a large stockpile of weapons-grade separated plutonium will be transformed into a stockpile of plutonium embedded in radioactive spent fuel—at least for some time to come.

The United States and Russia should agree that (a) the highest practicable standards of security and accounting will be maintained throughout the disposition process; and (b) all separated plutonium beyond the amount needed to support low, agreed numbers of warheads will be subject to disposition.[19] If the United

assumes, over-generously, that the 9 tons of excess plutonium announced in 2007 is entirely additional to the 34 tons covered under the 2000 disposition agreement and costs nothing to process.

[18] Areva officials indicate that there are now trades among utilities in which some utilities agree to burn MOX fabricated from other utilities' plutonium, suggesting that if the price were right, it might be possible to convince utilities to burn this MOX in Europe.

[19] For more detailed discussions, see Matthew Bunn and Anatoli Diakov, "Disposition of Excess Highly Enriched Uranium," and "Disposition of Excess Plutonium," in *Global Fissile Materials Report*

States and Russia agreed on those points, and also agreed that spent fuel from plutonium disposition (a) would not be reprocessed except when the plutonium was immediately going to be reused as fuel, and then under heavy guard, with stringent accounting measures, and (b) would only be reprocessed in ways that did not separate weapons-grade plutonium from fission products, and in which plutonium would never be separated into a form that could be used in a bomb without extensive chemical processing behind heavy shielding, then this disposition approach would deserve U.S. financial support. This is particularly the case as the BN-800 approach fits in to Russia's own plans for the nuclear energy future, unlike previous plans that focused on MOX in VVER-1000 reactors. If the United States does *not* provide promised financial support for disposition in Russia, Russia may conclude that it is free to use the BN-800 to breed more plutonium from this weapons plutonium, and to reprocess the spent fuel immediately, adding to Russia's huge stockpiles of separated plutonium. Congress should provide sufficient funding for NNSA to explore such approaches, and support them if agreement can be reached.

All of these approaches will take many years to implement. In the near term the United States and Russia should move to legally commit their excess material to peaceful use or disposal and place it under international monitoring to confirm that commitment—sending an important signal to the world that the United States and Russia are serious about their arms reduction obligations, at relatively minor cost.

2007 (Princeton, NJ: International Panel on Fissile Materials, October 2007, available at http://www.fissilematerials.org), pp. 24-32 and 33-42 as of 9 June 2008.

Disposition of Excess HEU

The current 500-ton HEU Purchase Agreement expires in 2013. Russia is likely to have hundreds of tons of additional HEU at that time that are not needed either to support its nuclear weapons stockpile or for naval and icebreaker fuel. Russia has made clear that it has no interest in extending the current implementing arrangements for the HEU Purchase Agreement, under which Russia faces higher costs and lower prices than it would marketing new-production commercial LEU. But a variety of other arrangements are possible that could create substantial incentives for Russia to blend down additional HEU. Congress should direct DOE to enter into discussions with Russia concerning a broad range of possible incentives the United States might be willing to provide to help convince Russia to blend down additional HEU—and should consider setting aside a conditional appropriation in the range of $200 million to finance such incentives if an agreement is reached that requires such funding.

Similarly, the United States can and should expand and accelerate the blend-down of its own excess HEU, beyond the roughly three tons per year now planned. For FY 2009, the Bush administration requested $39 million for U.S. HEU disposition, a 41 percent cut from the FY 2008 appropriation.[20] Congress should provide additional funding targeted to accelerating the effort to get the HEU out of warheads and their components and blended down to LEU as rapidly as practicable.

[20] U.S. Department of Energy, *FY 2009 Congressional Budget Request: National Nuclear Security Administration*, vol. 1, DOE/CF-024 (Washington, D.C.: DOE, 2008; available at http://www.cfo.doe.gov/budget/09budget/Content/Volumes/Volume1a.pdf as of 9 June 2008), p. 517.

5 PREVENTING NUCLEAR TERRORISM: AN AGENDA FOR THE NEXT PRESIDENT

The next U.S. president will take office still facing a very real danger that terrorists might get and use a nuclear bomb, turning the heart of a modern city into a smoldering ruin. Such an attack would change the world profoundly, with consequences going far beyond the horrific loss of lives and property. Preventing such an attack must be a top international security priority—for the next U.S. president, and for leaders around the world. The danger is real enough to justify President Bush's pledge to do "everything in our power" to keep nuclear weapons and the materials needed to make them out of terrorist hands.[1]

As the previous chapters of this report have made clear, existing programs have made substantial progress in reducing this risk. There is no doubt that the probability of a terrorist nuclear attack today is substantially lower than it would be if these programs had never been established.

But as the previous chapters of this report also make clear, there is far more yet to be done. Major gaps remain in existing efforts. On the current track, there is little prospect of reaching a state in which *all* of the world's stockpiles of nuclear weapons, highly enriched uranium (HEU) and plutonium have effective and lasting security in place. Nor, without major new initiatives, is there much prospect that a comprehensive global system to reduce the risk, with all of the highest-priority elements implemented, will be in place within the next 10-15 years. In short, there remains a dangerous gap between the urgency of the threat and the scope and pace of the U.S. and international response. Neither the United States nor any other country is doing "everything in our power" to reduce the danger of nuclear terrorism.

The political and bureaucratic obstacles to taking many of the needed steps are real and substantial. By and large, the easy actions have been taken—the low-hanging fruit is already plucked. Critical obstacles to expanded and accelerated progress include a powerful reluctance in many countries to having any other country or organization tell them what to do about nuclear security; political disputes among key countries; pervasive secrecy surrounding all aspects of nuclear security (particularly for military stockpiles), making cooperation difficult; strong incentives to cut corners on expensive and inconvenient security measures, from workers on the plant floor all the way up to national governments;[2] a wide range of bureaucratic impediments, from cumbersome contract review procedures to excessive reporting requirements;[3] and national se-

[1] President George W. Bush, "State of the Union Address" (Washington, D.C.: The White House, January 28, 2003; available at http://www.whitehouse.gov/news/releases/2003/01/20030128-19.html as of 16 August 2008.)

[2] 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).

[3] For suggestions on overcoming some of these impediments in the U.S. context, see Brian D. Finlay and Elizabeth Turpen, *Cooperative Nonproliferation: Getting Further, Faster* (Washington, D.C.: Stimson Center, January 2007). A condensed version is available as Brian D. Finlay and Elizabeth Turpen, *25 Steps to Prevent Nuclear Terror: A Guide to Policymakers* (Washington, D.C.: Stimson Center, January 2007).

curity establishments in the United States and other key countries around the world that are simply not well-structured to cope with this threat.[4]

But complacency is the most fundamental of the obstacles to progress. Policymakers and nuclear managers and staff around the world are complacent about the threat, believing that terrorists have little chance of getting a nuclear bomb or the material to make one, and little chance of being able to make or detonate a bomb if they did.[5] Many U.S. policymakers are also complacent about the progress of existing programs, believing that everything that needs to be done is already being done—or that steps still not taken are impossible to take, because of resistance in Russia or elsewhere that they assume can never be changed. Then-Undersecretary of State for International Security Policy John Bolton, for example, told the *Washington Post* in 2004 that he did not believe there was any "significant risk of a Russian nuclear weapon getting into terrorist hands," in part "because of all the money we've spent" on improving security for Russian warheads.[6] At the time of his statement, security upgrades had been completed for less than a third of Russian nuclear warhead sites—and the U.S. intelligence community was warning that very real risks continued to exist.[7]

Overcoming these obstacles to progress, and integrating and prioritizing the many steps that need to be taken, will not be easy. The needed efforts cut across multiple cabinet departments, and require cooperation in highly sensitive areas with countries across the globe. Breakthroughs will require sustained leadership, day-in and day-out, from the highest levels of government—in the United States and around the world. Far more than occasional supportive statements is required, for without continued focus from the top, key opportunities will be missed, critical problems will fester unresolved, and the global effort will still fail to match the

[4] For discussion of this point, see Cindy Williams and Gordon Adams, *Strengthening Statecraft and Security: Reforming U.S. Planning and Resource Allocation* (Cambridge, Mass.: Security Studies Program, Massachusetts Institute of Technology, June 2008, available at http://web.mit.edu/ssp/Publications/working_papers/OccasionalPaper6-08.pdf as of 14 August 2008); see also Charles B. Curtis, "Preventing Nuclear Terrorism: Our Highest Priority—Isn't," National Defense University, 21 May 2008, available at http://www.nti.org/c_press/speech_curtis_NDU_052108.pdf as of 14 August 2008. For an earlier summary of obstacles to accelerated progress, see "What Are the Main Impediments to Action?" 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. 74-75.

[5] For a selection of quotes—and responses to these mistaken impressions—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).

[6] Quoted in Barton Gellman and Dafna Linzer, "Unprecedented Peril Forces Tough Calls; President Faces a Multi-Front Battle against Threats Known, Unknown," *Washington Post*, 26 October 2004 available at http://www.washingtonpost.com/wp-dyn/content/article/2004/10/26/AR2005033113163.html as of 11 November 2008.

[7] As shown in Figure 3.2 (compiled from official U.S. government data), by the end of fiscal 2004, only 36 Russian warhead sites had U.S.-funded security upgrades completed; most of these were Russian Navy sites that received only limited rapid upgrades. For a U.S. intelligence assessment at the time of Bolton's statement, see 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).

scope of the threat. The terrorists seeking nuclear weapons are focused, intelligent, linked to global networks of allies, and able to adapt to setbacks and try new approaches; the effort to stop them must match these qualities.

But there is no cause for fatalism: nuclear terrorism is a real and urgent danger, but it can be prevented.[8] With sufficient leadership, the obstacles to progress can be overcome, or creative ways around them can be found. Indeed, the next U.S. president has an historic opportunity—an opportunity to take feasible, affordable actions that could reduce the risk of nuclear terrorism to a small fraction of its current level by the end of his first term.

The U.S.-Russian nuclear security initiative launched at the Bush-Putin summit in Bratislava in 2005 provides an example of the potential results of presidential leadership. As a result of this initiative, both governments have focused money and people on getting the agreed security upgrades finished by the end of 2008; given responsibility for following-through to key officials and established processes for regular review of importance; expanded the number of nuclear material buildings and warhead sites that will receive security upgrades; and deepened their dialogue on critical issues such as strengthening security culture, budgeting for nuclear security, and more. Similarly, Ukraine's April 2008 agreement in principle to blend down all its HEU represents the result of a sustained effort that included top officials from both the U.S. and Ukrainian governments.

[8] This insight is encapsulated in the title of Graham Allison's seminal book on the subject: Graham T. Allison, *Nuclear Terrorism: The Ultimate Preventable Catastrophe*, 1st ed. (New York: Times Books/Henry Holt, 2004).

But there are also lingering dangers that highlight the result of failure to provide sustained and creative high-level leadership in overcoming obstacles. Years of effort to convince Belarus to give up its dangerous but largely unused HEU stocks have yet to bear fruit. As of October 2008, South Africa had not agreed either to eliminate its HEU stock or even to participate in cooperative efforts to upgrade security, despite the break-in at its Pelindaba site in November 2007. (South Africa did convert its research reactor to use LEU fuel, but is still using HEU targets to produce medical isotopes.) The Mayak Fissile Material Storage Facility, a secure site for storing bomb material built with over $300 million in U.S. assistance, stood empty for nearly three years after it was completed in 2003, and still contains only a tiny fraction of the material it was built to store. As Chapter 2 makes clear, the list goes on.

From Iraq to al-Qaeda, from Iran to North Korea, from the Middle East to Russia and its neighbors, from Pakistan and Afghanistan to Sudan, from climate change to global trade, the next U.S. president will face a complex array of urgent issues clamoring for his attention. The effort to keep nuclear weapons and the materials to make them from falling into terrorist hands must not be allowed to slide to the back burner.

This chapter provides an agenda for that effort—one designed to achieve rapid reductions in the risk of nuclear terrorism, focusing on the highest priorities first. The probability of nuclear terrorism can never be reduced to zero—but it is essential to focus on getting as close to that objective as possible, as quickly as possible. This chapter focuses first on the highest priority—achieving effective and sustainable security for all stocks of nuclear weapons and the materials needed to make them worldwide. It then addresses steps to stop the other elements of terrorist nuclear plots, to provide the needed sustained leadership and build the sense of urgency and commitment around the world, and to put the United States' own house in order.

Achieving Effective and Lasting Nuclear Security Worldwide

The first and most important step to be taken is to ensure that *all* stocks of nuclear weapons and the materials needed to make them wherever they may be in the world, are secured and accounted for, to *standards* sufficient to ensure that they are defended against the threats that terrorists and thieves have demonstrated they can pose, in ways that will *work,* and will *last.* Improving nuclear security is the one step that can be taken that will most reduce the overall risk of nuclear terrorism—for once a nuclear weapon or nuclear material has left the facility where it is supposed to be, it could be anywhere, and all the subsequent layers of defense are variations on looking for needles in haystacks. Several steps, in addition to those already underway, are needed to achieve this objective.

Launch a fast-paced global nuclear security campaign

The next president, working with other world leaders, should forge a fast-paced global campaign to lock down every nuclear weapon and every significant stock 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.[9] The Global Initiative to Combat Nuclear Terrorism is a first step, which has been valuable in focusing countries' attention on the issue of nuclear terrorism and building legal infrastructure, capacity for emergency response, law enforcement capabilities, and more—but it has not focused on rapid and substantial security upgrades for nuclear stockpiles, and demands little of countries to count as partners. A modified approach—focused on locking down all stocks of nuclear weapons, plutonium, and HEU to high standards—is likely to be necessary to create the kind of fast-paced nuclear security campaign that is needed.

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 stock of HEU and plutonium worldwide is secure enough so that the risk of nuclear theft and terrorism it poses is very low—rather than each of these tools being pursued independently, often by officials with little awareness of what efforts on other tracks are doing and the potential implications, as is currently the case.

[9] This includes measures such as consolidating nuclear stockpiles, establishing effective nuclear security standards, and strengthening sustainability and security culture, discussed below as separate initiatives.

Goals for a global nuclear security campaign. The next president should work 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. (Effective approaches to nuclear security standards are discussed in more detail below.)
- Work with other states to convince them to join the commitment to this common standard and provide assistance where necessary to help countries put this 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, with participants using their own resources, after any international assistance they may be receiving or may require to attain the standards comes to an end.
- Reduce the number of locations where nuclear weapons and weapons-usable nuclear materials are located to the minimum possible and eliminate such stocks from difficult-to-defend locations, achieving higher security at lower cost.
- Establish targeted programs to achieve and maintain strong security cultures among all nuclear-security-related personnel.
- Put in place border and transshipment 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.

The goal of this campaign should be take concrete actions to achieve these goals 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.

Mechanisms for follow-through. An effective global campaign will need strong mechanisms for ensuring that the initial commitments move from pledges to deeds. It may be that such a mechanism can be established as part of the Global Initiative to Combat Nuclear Terrorism, though the participants in the Global Initiative have so far been extremely reluctant to endorse having foreign countries review their progress in meeting their commitments, and a progress review group established shortly after the initiative was launched has been allowed to atrophy.[10]

The Bratislava initiative—in which the two Presidents gave responsibility for implementation to the U.S. Secretary of Energy and the director of what was then the Federal Atomic Energy Agency of Russia (Rosatom, now a state corporation), and demanded reports every six months on progress in meeting an agreed set of milestones—provides an example of a follow-up mechanism that has worked effectively. It combined creating a single locus of responsibility on each side (though in this case one with little authority to overrule other agencies when they were creating obstacles to progress) with a regular mechanism for accountability for progress.

Following that example, key participants in the nuclear security campaign should each designate senior officials to be responsible for all aspects of implementing these commitments, and these senior officials should meet regularly to develop agreed plans with measurable milestones, to oversee progress in implementation, 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.

Funding a global campaign. 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 implement them 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—particularly as the Group of Eight (G8) industrialized democracies agreed

[10] Interview with U.S. Department of State officials, July 2008.

at their 2008 summit agreed to extend the Global Partnership worldwide and to make nuclear security one of its key priorities.[11]

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—could convince some states to provide additional contributions, finally bringing the total up to the $20 billion initial target or more and providing sufficient funds to implement the needed steps for all countries requiring assistance worldwide.[12] (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 a total 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 included a commitment to take the steps necessary to "prevent terrorists, or those that harbor them, from acquiring" the materials needed for weapons of mass destruction; specifically 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 effective security.[13]

Implementing UN Security Council Resolution 1540. UNSCR 1540 creates binding legal obligations on all states to take many of the steps just outlined—to provide "appropriate effective" security and accounting for any nuclear stockpiles they may have, to pass and enforce effective laws criminalizing nuclear theft and terrorism, to put in place effective border controls to help stop nuclear smuggling, and more. Much of what a global nuclear security campaign should do can be framed as simply implementation of UNSCR 1540—and implementing a binding legal obligation established at the United Nations may motivate many countries in a way that simply going along with a new initiative led by the United States or other developed weapons states would not.

Building real nuclear security partnerships. To succeed, a global nuclear security campaign must 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.[14] For

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[11] See *G8 Hokkaido Toyako Summit Leaders Declaration* (Hokkaido Toyako, Japan: Group of Eight, 8 July 2008, available at http://www.g8summit.go.jp/eng/doc/doc080714__en.html as of 22 July 2008), and *Report on the G8 Global Partnership* (Hokkaido Toyako, Japan: Group of Eight, July 2008, available at http://www.g8summit.go.jp/doc/pdf/0708_12_en.pdf as of 22 July 2008). For the original announcement of the Global Partnership, see "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 8 July 2008).

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

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

[14] For an especially useful discussion of strengthening nuclear security cooperation through partnership-based approaches in the U.S.-Russian context, 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 18 June 2008). See also

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.

There are critically important cases where political conflicts are likely to make building genuine partnerships difficult. U.S.-Russian relations, for example, have been deteriorating for years, and the Russian-Georgian war is likely to color Russia's relations with the United States with suspicion and tension for years to come. Nunn-Lugar cooperation has weathered these storms remarkably well in the past—sometimes serving as one of the main remaining channels for the two countries to discuss critical weapons-related issues. But as political relations sour, "donor fatigue" builds on the U.S. side, resistance to ongoing donors' demands builds on the Russian side, and Russia's growing economy makes cooperation seem less and less urgent, cooperation to address remaining nuclear security issues will inevitably become more difficult—particularly when it comes to launching new initiatives that may intrude into sensitive areas in new ways, or even reaching new agreements that may be necessary to maintain existing cooperation (such as a replacement for the expired Warhead Safety and Security Exchange (WSSX) agreement).

Similarly, a wide range of factors will continue to make it difficult to forge a genuine nuclear security partnership with Pakistan. These include ongoing disputes among different factions in Pakistan; continuing tensions over U.S. demands for more action against al-Qaeda and other violent extremists in the tribal areas of Pakistan and over ongoing U.S. missile strikes on targets there; and rising Pakistani anti-Americanism and suspicion of U.S. motives.

Yet success in building such nuclear security partnerships is essential—to the interests of the United States, Russia, Pakistan, and the world. This is among the areas where sustained and creative top-level leadership will be indispensable. How best to build and sustain action on nuclear security must be a central factor considered in making choices concerning each of the many policies that affect U.S. relations with Russia and Pakistan (and with their nuclear establishments in particular).

Joint U.S.-Russian nuclear security teams. The United States and Russia have the world's largest nuclear stockpiles and the world's most extensive nuclear security experience. As President Bush and President Putin acknowledged in their 2005 Bratislava nuclear security initiative, the two countries bear a "special responsibility" for nuclear security. Moreover, after more than 15 years of Nunn-Lugar cooperation, the United States and Russia have extensive experience in cooperating to find and fix weaknesses in nuclear security and accounting, and in finding ways to overcome obstacles posed by secrecy, sovereignty, and other constraints (though some of these problems are still

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 8 July 2008).

unresolved). Russia now has a cadre of experts well-trained in assessing nuclear security vulnerabilities, designing effective nuclear security systems, and building and installing needed equipment—as well as substantial resources.

The time has come for a more decisive shift from a donor-recipient relationship to a true partnership for nuclear security extending far beyond Russia's borders. The United States and Russia should establish joint teams that can, on request, help countries around the world to meet their UNSCR 1540 obligations to provide effective nuclear security and accounting. These teams could help countries review their nuclear security arrangements, design and install systems to fix any weaknesses identified, strengthen nuclear security regulations—and the two countries should jointly help pay for these needed upgrades.[15]

Bilateral cooperation as part of a global campaign. Of course, bilateral cooperation with particular states will be a key policy tool in such a global nuclear security 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 equals, framed as one part of a global approach.

The United States and Russia are planning to complete the nuclear security upgrades agreed to in the Bratislava initiative by the end of 2008. Upgrades at some additional buildings agreed to after Bratislava are slated to be completed in the year or two thereafter. NNSA then envisions a period lasting from 2008 though the end of 2012, during which U.S. funding will phase down and Russian funding will phase in, followed by continuing low-level cooperation to exchange best practices and resolve ongoing issues either side may face.[16] (Current U.S. law requires that NNSA aim for an effective nuclear security system in Russia supported entirely by Russian resources by January 1, 2013.)

Russia today has a growing economy, surging oil revenues, and a substantial budget surplus. The Russian government *could* afford to manage nuclear security effectively without U.S. help—but it is not yet giving nuclear security the priority it requires. Until that allocation of priorities changes, without U.S. funds dangerous nuclear security vulnerabilities would continue unfixed, posing direct threats to U.S. and world security. The best risk-reduction strategy, therefore, is for the United States to continue to invest in nuclear security in Russia, during the transition period through 2012, while simultaneously seeking to convince the Russian government to increase its investment and take full responsibility for nuclear security itself. Already, there are some signs of increased Russian commitment: the NNSA-Rosatom agreement on sustainability in 2007 (which accepts in principle that U.S. funding will phase out and be replaced by Russian funds); the decision by the 12th Main Department of Russia's Ministry of Defense (known by its

[15] This concept of joint U.S.-Russian nuclear security teams has been suggested by former Senator Sam Nunn, as a key part of building a genuine U.S.-Russian partnership for nuclear security.

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

Russian acronym as the 12th GUMO), the force in charge of Russia's nuclear weapons, to seek additional funding from the Russian Finance Ministry to sustain security at warhead sites without requiring U.S. assistance; and the detailed plans that an increasing number of Russian sites are laying out (in cooperation with NNSA) to transition to financing nuclear security without U.S. help, are all steps in the right direction.

A critical next step—and a fitting follow-on to the Bratislava initiative—would be for the United States to seek a Russian commitment at the presidential or prime ministerial level 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. At the same time, 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, and 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 sustainability and security culture below.)

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.[17] Cooperation with states with smaller 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.

Promoting and exchanging "best practices" among nuclear security operators. As has been the case for nuclear safety, establishing a forum where operators could exchange information on best practices, lessons learned from particular problems and incidents, and successful methods for addressing particular issues that arise could be a major step forward in nuclear security, and should be part of a global nuclear security campaign. Such

[17] For discussion, see "Challenges of Adapting Threat Reduction to New Contexts," in Bunn and Wier, *Securing the Bomb: An Agenda for Action*, pp. 104-105. See also 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 percent20for percent20a percent20New percent20Era.pdf as of 21 March 2005); 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 2 July 2008); 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).

a forum—dubbed the World Institute for Nuclear Security (WINS)—was launched in September 2008, headquartered in Vienna.[18] WINS was developed through a partnership between the Nuclear Threat Initiative (NTI) and the Institute for Nuclear Materials Management (INMM), with support from NNSA, and has been gaining endorsements and support from institutions ranging from the IAEA to nuclear firms and agencies in Britain, Norway, the United States, and elsewhere.

To ensure that such an initiative has the necessary clout, it will be important to develop it in a way that maximizes buy-in from nuclear operators themselves, and particularly from those controlling the purse-strings. In the safety area, what made the World Association of Nuclear Operators (WANO) and its U.S.-based predecessor, the Institute of Nuclear Power Operations (INPO) so effective was that the nuclear 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.[19]

Incentives for nuclear security. The key participants in a global nuclear security campaign should act to give states and facilities strong incentives to provide effective security for their nuclear stockpiles.[20] 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 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 these 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 supporting DOE nonproliferation programs) for facilities that 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.

Ensure the global nuclear security campaign covers *all* nuclear stockpiles. Terrorists will get the material to make a nuclear bomb wherever it is easiest to steal. The world cannot afford to let stovepipes between different programs leave some vulnerable stocks without security upgrades—the goal must be to ensure effective security for *all* stocks worldwide. Today, as described in Chapter 2, security upgrades in Russia are nearing completion, and there is significant progress in Pakistan, but the promising nuclear security dialogue with China does not yet appear to have led to major improvements in nuclear security

[18] For a brief introduction to WINS, see "NTI in Action: World Institute for Nuclear Security (WINS)," available at http://www.nti.org/b_aboutnti/b7_WINS.html as of 30 October 2008, and documents available there. The WINS website, which so far has limited information posted, was available at http://www.wins.org as of 30 October 2008.

[19] For a fascinating discussion of INPO, its record of effectiveness, and the factors that caused that outcome, see Joseph V. Rees, *Hostages of Each Other: The Transformation of Nuclear Safety since Three Mile Island* (Chicago: University of Chicago, 1996).

[20] Bunn, "Incentives for Nuclear Security."

there, and India has so far rejected offers of nuclear security cooperation. South Africa has not yet accepted nuclear security cooperation, despite the break-in at Pelindaba in November 2007. Except for occasional bilateral dialogues, U.S. programs largely ignore stocks in wealthy developed countries, though some of these, too, are dangerously insecure.[21] Under current plans, the Global Threat Reduction Initiative (GTRI) will remove only about a fifth of the estimated 15.9 tons of U.S.-origin HEU abroad. There is currently no U.S. program to limit the production, use, and stockpiling of weapons-usable separated civilian plutonium. U.S. programs should focus on the total problem, eliminating these gaps. A global nuclear security campaign must be truly global.

Expand and accelerate efforts to consolidate nuclear stockpiles

The next U.S. president should place higher priority on working with countries to reduce drastically the number of sites where nuclear weapons and the materials to make them exist, achieving higher security at lower cost. As argued above, the goal should be to remove all nuclear material from the world's most vulnerable sites and ensure effective security wherever material must remain within four years or less—and to eliminate HEU from all civilian sites worldwide within roughly a decade.[22] These are challenging goals, but with sufficient leadership and an expanded set of policy tools, there is reason to hope that they could be accomplished.

The United States and other concerned countries 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.[23] (It would be ideal if a country other than the United States would step up and take the lead in pushing for steps toward phasing out the civil use of HEU.) For some years to come, there may still be a small number of HEU-fueled facilities generating unique data that cannot be gained by other means. But any facility using any significant amount of this material must be required to maintain stringent security measures—and the costs of doing so are likely to motivate a rapid search for alternatives to using HEU.

Success in this effort will require focusing on a broader set of materials and facilities to consolidate, and a broader set of policy tools and incentives with which to address them.

A broader set of materials and facilities. Consolidation efforts should go far

[21] While specific tactics are likely to differ—achieving security upgrades in wealthy countries may be more about convincing them that action is needed than it is about paying for it ourselves—it is urgent to get past the assumption that everything in wealthy countries is adequately secured.

[22] 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.

[23] For an excellent recent exploration of these issues, see the special section on minimizing civil HEU in *Nonproliferation Review,* Vol. 15, No. 2 (July 2008).

beyond converting HEU-fueled research reactors to LEU, as important as that is. The global campaign should seek to consolidate nuclear warheads, consolidate both civil and military HEU, and consolidate both military and civilian plutonium. Each of these efforts will require different strategies and approaches, but all should be pursued with vigor. The focus should be on whether the particular stock poses a security risk, not whether it fits within the stovepipe of a particular program.

With respect to HEU-fueled research reactors, GTRI took a major step in early 2007, adding 23 HEU-fueled reactors to the list of facilities it would like to convert to LEU, bringing the total to 129. (Of these, 56 were already converted or shut down by the spring of 2008, leaving 73 remaining on the list targeted for conversion at that time.) But even after this expansion, more than 40 percent 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.

Ultimately, conversion or shut-down efforts should also seek to address Russia's HEU-fueled nuclear icebreakers; reactors for naval ships and submarines, especially in the United States and Russia; Russia's plutonium and tritium production reactors; and the BN-600 commercial power reactor, none of which are included in current programs.

Moreover, efforts to minimize civil use of weapons-usable nuclear material should focus on plutonium as well. 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.[24] The United States and other leading countries should work to minimize the use of weapons-usable material by *all* reactors, examining each use case-by-case to see what opportunities exist for convincing reactors to shut or to convert to fuels and targets made from material that cannot be used in a nuclear bomb—or, failing that, what security and accounting improvements can be put in place to reduce the risks. Where possible, the United States should work with other countries to end unnecessary accumulation of additional stockpiles of separated plutonium; the next U.S. president, for example, should again take up the effort the nearly-completed Clinton-era effort to reach agreement with Russia on a 20-year moratorium on further plutonium separation in the two countries.

[24] It is important to understand that "reactor-grade" plutonium, despite its name, can also be used to make nuclear weapons. Reactor-grade plutonium would not be the preferred material for making nuclear weapons, because of its higher neutron generation, heat, and radiation levels—but any state or group that could make a bomb from weapons-grade plutonium could also make a bomb from reactor-grade plutonium. A bomb using the same level of technology used in the Nagasaki bomb would have an assured, reliable yield in the kiloton range (and a probable yield higher than that); advanced states such as the United States and Russia could make nuclear weapons with reactor-grade plutonium with yield, weight, and reliability comparable to those of weapons made from weapon-grade plutonium. For a particularly detailed official unclassified statement on this topic, 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 13 May 2008), pp. 38-40.

At a minimum, the United States should not encourage commercial reprocessing and recycling of plutonium, as some of the approaches proposed in the Global Nuclear Energy Partnership (GNEP) would do; even the proposed GNEP processes that do not separate "pure plutonium" would tend to increase, rather than decrease, the risk of nuclear theft and proliferation compared to not reprocessing this fuel.[25] 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."[26] Wherever plutonium use continues, ensuring security commensurate with the risks must 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 plutonium in forms that could be used in weapons without extensive further processing in heavily shielded facilities.

One absolutely critical tool in the global effort to consolidate weapons-usable materials is the effort to remove material from facilities around the world and ship it to secure facilities in the country of origin or elsewhere. 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 DOE should complete the necessary environmental assessments to pave the legal path for vulnerable nuclear material to be brought to the United States for disposition when that is the best available option. 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 go even further in consolidating nuclear material in the DOE weapons complex than it has yet done, and work with Russia to convince Russia to do the same. The two sides should develop 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

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25 For a more extended discussion, see Matthew Bunn, "Risks of GNEP's Focus on Near-Term Reprocessing," testimony before the Committee on Energy and National Resources, U.S. Senate, 14 November 2007, available at http://belfercenter.ksg.harvard.edu/files/bunn-GNEP-testimony-07.pdf as of 28 April 2008. See also Edwin Lyman and Frank N. von Hippel, "Reprocessing Revisited: The International Dimensions of the Global Nuclear Energy Partnership," *Arms Control Today,* April 2008, available at http://www.armscontrol.org/act/2008_04/LymanVonHippel.asp as of 28 April 2008.

26 "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).

pursue consolidation opportunities in these countries as well.

The United States should also work with Russia to consolidate warheads at a much smaller number of locations.[27] In particular, the United States and Russia should launch a major nuclear warhead consolidation and security initiative, as described below. 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,[28] 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.

A broader set of policy tools and incentives. Today, many operators of HEU-fueled research reactors have few incentives to shift to LEU—a fuel they are less familiar with, which may have at least modest disadvantages. No program exists to give operators of little-used HEU-fueled reactors—or those who provide the subsidies that allow these facilities to continue to operate—incentives to shut down and get rid of their HEU. Nor are any programs in place to create incentives to reduce the number of sites where nuclear warheads or separated plutonium exist. Wealthy countries must pay a hefty fee to get rid of their HEU, either by sending it to the United States or by sending it to France for reprocessing—with the result that only a tiny fraction of their U.S.-origin HEU is likely to be returned to the United States. As part of the global campaign described above, the United States should work with other countries to close these gaps, using a comprehensive set of policy tools and incentives to encourage consolidation.

First, there is a critical link between effective (but costly) nuclear security and incentives for consolidation. As part of the global campaign described above, the United States and other key countries should strive to ensure that every country where nuclear weapons or significant stocks of HEU or separated plutonium exist puts in place and effectively enforces regulations requiring that this material be protected against the kinds of threats that terrorists and criminals have shown they can pose. This will help ensure effective security for these materials—and the cost of complying with such regulations will provide a powerful incentive to get rid of such materials wherever possible.[29] (Indeed, reducing the cost of meeting post-9/11 security standards has been a principal goal of the large-scale consolidation of nuclear materials in DOE's nuclear complex; in 2008, DOE completed the removal of weapons-usable nuclear material from the Sandia National Laboratory, shutting down two no-longer-needed HEU-fueled research reactors to do so, saving tens of millions of dollars a

[27] For similar recommendations, see 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 8 July 2008), p. 19; 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 8 July 2008).

[28] 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).

[29] The goal of reducing the costs of post-9/11 security requirements is a major factor driving the large-scale consolidation at DOE's nuclear complex, in which Sandia National Laboratory was cleared of potential weapons material this year (including the shutdown of two research reactors), saving tens of millions of dollars a year in security costs.

year in security costs.[30]) In particular, the U.S. Congress should direct the Nuclear Regulatory Commission (NRC) to phase out the exemption from most security requirements for HEU that NRC-regulated research reactors have long enjoyed, and provide sufficient funding for DOE, which provides most of the operating budget of these reactors, to cover the resulting increased security costs (which would be a tiny fraction of the $1.5 billion spent each year on DOE security). Similarly, Russia should modify its security regulations to permit nuclear sites that have only low-enriched uranium (LEU) to save money by having less security than facilities with HEU.[31]

Second, the United States should work with other interested states and international organizations such as the IAEA to structure packages of incentives targeted to the needs of each reactor to convince operators of HEU-fueled research reactors (and the ministries and regulators that oversee them) to convert to LEU. Many operators of HEU-fueled reactors today have little interest in converting to LEU, and new incentives are likely to be essential to convince some of them. As just one example, donor countries could more than compensate for the few-percent reduction in neutron flux that reactors tend to suffer after converting to LEU by offering to finance new neutron guides, which can increase the neutron flux available at the actual experiment locations by more than a factor of ten, at modest cost.[32] Putting together such packages of incentives will require some broadening of current thinking and an expansion of current budgets (which do not include 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 they are not significantly worse off as a result of conversion—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.[33] This policy should be reversed.[34]

Third, it is important to add incentives to convince little-used reactors to shut down as a complementary policy tool to conversion. Nearly half of the world's currently

[30] See, for example, U.S. Department of Energy, National Nuclear Security Administration, "First Phase of Nuclear Material Consolidation Complete" (Washington, D.C.: NNSA, 28 February 2008, available as of 25 August 2008 at http://www.nnsa.energy.gov/news/1800.htm).

[31] Russia's 1997 physical protection regulations required effectively the same security measures for LEU as for HEU. In a July 2007 conversation with V.P. Struyev, director of the Krylov Shipbuilding Institute, the first Russian facility to eliminate all of its HEU in cooperation with DOE's Material Conversion and Consolidation program, Struyev indicated that for this reason, he expected no security savings as a result of giving up HEU—a situation that gives Russian facilities little incentive to consider changing their reliance on HEU. The new Russian physical protection regulations are more graded, but exactly what savings a facility could realize by eliminating its HEU remains unclear.

[32] Alexander Glaser, "Neutron-Use Optimization with Virtual Experiments to Facilitate Research-Reactor Conversion to Low-Enriched Fuel," in *Proceedings of the Institute for Nuclear Materials Management 48th Annual Meeting, July 8–12, 2007, Tucson, Arizona* (Northbrook, Ill.: INMM, 2007).

[33] In one case in Kazakhstan, the Nuclear Threat Initiative has stepped in to offer help with upgrades associated with a research reactor conversion, so that the reactor will be more competitive after conversion than before.

[34] 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.

operating HEU-fueled research reactors are not on the Global Threat Reduction Initiative's list targeted for conversion (and many of those that *are* on GTRI's list may be cheaper and easier to shut down than to convert). Unlike conversion, shut-down need not wait for the development of new fuels; it can be pursued immediately. Even in the absence of any targeted incentives, nearly twice as many HEU-fueled reactors have shut down since conversion efforts began as have converted, showing the potential power of the shut-down tool.[35] 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.[36]

But no research reactor operator wants to shut his or her facility—meaning that substantial packages of incentives are likely to be needed. The IAEA, with support from the Nuclear Threat Initiative (NTI), is helping research reactors establish coalitions to share information, improve their strategic planning, allow other research or isotope reactors to step in when one facility has an unexpected outage, and more.[37] These coalitions could make it possible for scientists from reactors that can no longer afford to keep operating to make use of other facilities in their region. But these coalitions are not structured to provide positive incentives for underutilized reactors to shut down. How should such incentives be provided? 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. Incentives packages might include funding research at a site that does not require the research reactor, funding research as a user group at another facility in the region, or helping with shutdown and decommissioning. In some cases, the appropriate target of such discussions may be national-level decision makers who subsidize these reactors' operation. Such shut-down incentives should be institutionally separated from conversion efforts, so that the trust necessary to convince operators to convert is not undermined by the operators believing the real agenda of the conversion experts is to shut them down. 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.

Fourth, market incentives should be used to convince the major producers of the principal medical isotope, molybdenum-99, to shift production away from the use of HEU targets. A user fee imposed on all medical isotopes made using

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[35] See the data presented in Ole Reistad and Styrkaar Hustveit, "HEU Fuel Cycle Inventories and Progress on Global Minimization," *Nonproliferation Review* 15, no. 2 (July 2008); Ole Reistad and Styrkaar Hustveit, "Appendix II: Operational, Shut Down, and Converted HEU-Fueled Research Reactors," *Nonproliferation Review* 15, no. 2 (July 2008; available at http://cns.miis.edu/pubs/npr/vol15/152_reistad_appendix2.pdf as of 3 July 2008).

[36] 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).

[37] See, for example, Ira N. Goldman, Pablo Adelfang, Arnaud Atger, Kevin Alldred, and Nigel Mote, "Developing Research Reactor Coalitions and Centres of Excellence," presentation at "Research Reactor Fuel Management 2007," (Lyon, France, 12 March 2007, available at http://www.igorr.com/home/liblocal/docs/Proceeding/Meeting percent2011/Goldman.pdf as of 30 September 2008.)

HEU, amounting to roughly 30 percent of the value of the isotopes, would create a powerful incentive to convert from HEU. Because the isotopes represent a tiny fraction of the cost of the medical procedures that use them, this fee would have little effect on patient costs or the availability of needed isotopes. The revenue could be used to assist producers willing to convert.[38]

Fifth, the United States and other concerned states should offer additional incentives to convince key potentially vulnerable HEU, plutonium, or nuclear warhead sites to allow those stockpiles to be removed. The history of successful HEU-removal efforts such as Project Sapphire in 1994 and Project Vinca in 2002 makes clear that incentives targeted to the needs of a particular country or facility can be essential to success—and that the needed incentives are likely to be different in each particular case, suggesting the need for flexible and creative approaches.[39] Additional incentives may well be necessary to convince Belarus and South Africa to give up their particularly dangerous high-quality HEU stocks. As described in Chapters 2 and 3, only a tiny fraction of the U.S.-origin HEU in developed countries is expected to be shipped back to the United States—in part because the United States charges these countries a hefty fee to take this material, discouraging them from doing anything other than letting it build up at reactor sites.[40] The United States should (a) reduce the amount it charges to accept this HEU; and (b) launch a broad offer to purchase potentially vulnerable HEU from any country willing to give it up. The United States might offer $25,000 per kilogram, for example—roughly the original price agreed to in the U.S.-Russian HEU Purchase Agreement—for HEU from any country, with any HEU provided being stored and eventually blended to LEU.[41]

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[38] 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. For useful assessments of the issues surrounding the use of HEU for medical isotopes, see, for example, Cristina Hansell, "Nuclear Medicine's Double Hazard: Imperiled Treatment and the Risk of Terrorism," *Nonproliferation Review,* Vol. 15, No. 2, July 2008, pp. 185-208, and Frank N. von Hippel and Laura H. Kahn, "Feasibility of Eliminating the Use of Highly enriched Uranium in the Production of Medical Radioisotopes," *Science and Global Security* Vol. 14 (2006), pp. 151-162, available at http://www.princeton.edu/~globsec/publications/pdf/14_2-3_percent20FvH_LK_Radio.pdf as of 2 August 2008. Alan Kuperman has been a particularly consistent and well-informed advocate for shifting medical isotope production to LEU. See, for example, Alan J. Kuperman, "The Global threat Reduction Initiative and Conversion of Isotope Production to LEU Targets," in *Proceedings of the 26th International Meeting on Reduced Enrichment in Research and Test Reactors,* Vienna, 7-12 November 2004, available at http://www.rertr.anl.gov/RERTR26/Abstracts/17-Kuperman.html as of 2 August 2008.

[39] See, for example, 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/BCSIA_content/documents/bleekglobalcleanout.pdf as of 18 July 2008).

[40] 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).

[41] The offer might include discounts for material that posed less proliferation risk, such as HEU in the 20-40 percent enrichment range, or heavily irradiated HEU. (As discussed in Chapter 2, irradiated research reactor fuel, unlike spent fuel from commercial power reactors, continues to pose a risk of theft, as the fuel elements are small and easily removed, still contain HEU, and are not radioactive enough to disable or even sicken terrorists attempting to steal them.) For an earlier discussion of such an HEU purchase offer, see Matthew Bunn, *The Next Wave: Urgently Needed New Steps to Control Warheads and Fissile Material* (Washington, D.C.: Managing the Atom Project, Harvard University, and Non-Proliferation Project, Carnegie Endowment for International Peace, 2000;

If, in fact, there are roughly 19 tons of HEU outside of the United States and Russia, the cost of such an offer could come to less than half a billion dollars even if it succeeded in eliminating every kilogram of this material (though of course there would also be substantial costs for packaging, shipping, and disposition of the materials that countries agreed to send).

Finally, in addition to incentives, the United States and other concerned countries must give consolidating nuclear stockpiles the diplomatic priority they deserve. To date, these effort have often been treated as "nice to do" but not urgent, items to be handled largely by program managers and technical experts. Instead, eliminating sites where nuclear weapons, HEU, or separated plutonium could be stolen must be seen as a critical element of the global effort to keep nuclear bomb material out of terrorist hands, and therefore a high priority for U.S. diplomacy—an item to be raised with presidents and prime ministers whenever that is the best way to get the job done.[42]

Gain agreement on effective global nuclear security standards

Nuclear security is only as strong as its weakest link; insecure nuclear materials anywhere are a threat to everyone, everywhere. Hence, the next U.S. president and other world leaders should seek rapid agreement on effective global nuclear security standards, designed to ensure that all nuclear weapons and weapons-usable materials are protected against the kinds of threats terrorists and criminals have shown they can pose.

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. One approach would be to focus on the kinds of threats nuclear weapons and the materials needed to make them should be protected against. There should be a minimum level of security required everywhere, but security measures capable of defending against still larger threats should be put in place in countries where terrorists and thieves are especially active and capable. For example, the agreed global minimum might be that all nuclear weapons and significant stocks of weapons-usable nuclear materials must be protected at least against two small teams of well-trained, well-armed attackers, possibly with inside help—the level of capability demonstrated in the Pelindaba break-in in November 2007—or a well-placed insider acting alone.

Different countries are likely to take different approaches to meeting the objective. In some countries, where labor rates are low and advanced technologies are hard to purchase and maintain, an approach focused on large numbers of armed guards may work best; in others, a technology-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.

available at http://belfercenter.ksg.harvard.edu/files/fullnextwave.pdf as of 12 May 2008), pp. 78-79. New consideration of this concept was recently suggested to me by Devabhaktuni Srikrishna, chief technology officer for a wireless networking firm. Personal communication, August 2008.

[42] 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.

How might general agreement on such a global standard be reached? Several paths are possible. None offer an easy or sure means to reach the objective. Past efforts make clear that there is strong resistance by many countries to agreeing to a standard that might force them to spend more on nuclear security, or to change approaches that they believe are already adequate. Here, complacency over existing approaches blends with concerns over national sovereignty to create a major obstacle to agreement.

For these reasons, recent agreements such as the nuclear terrorism convention[43] and the amendment to the physical protection convention,[44] 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 have been assigned to "experts" far removed from the centers of power, who, having come up through a national system that handles nuclear security in a particular way, generally see little need to change that approach and considerable potential for added costs and unwanted intrusion for the nuclear industries and ministries they represent. Indeed, these representatives, far removed from the centers of power in their respective governments, typically do not have the power to agree to measures that would require substantial changes in the way their countries handle nuclear security even if they wanted to do so.

By contrast, top political leaders charged with managing the full spectrum of their nation's security, when asked whether nuclear weapons and the materials needed to make them should be protected against an insider trying to steal them, or two small teams of outside attackers, are likely to say "of course they should." Hence, the most plausible means to overcome the obstacles to a global nuclear security standard is to gain political commitments from senior political leaders—perhaps at the G8 summit—to a very broadly defined standard—perhaps expressed in only a paragraph or two—with experts assigned to flesh out the specifics only after the top leaders had approved a clear direction. 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.

Regardless of whether international agreement has yet been reached on such global nuclear security standards, the next U.S. president should direct U.S. agencies, in pursuing bilateral cooperation to upgrade nuclear security in other countries, to adopt the goal of achieving a level of security that matches the standards the United States is advocating, and 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. This would serve U.S. security interests far better than relying on least-common-denominator standards such compliance with existing IAEA physical protection recommendations. In many cases, this

[43] *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 16 September 2005). This treaty's most specific provision related to security of nuclear stockpiles is a requirement that all parties "make every effort to provide appropriate measures to ensure the protection" of nuclear and radiological materials (Article 8).

[44] *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 25 June 2008).

may require more substantial upgrades than have yet been undertaken, or more efforts to convince recipient states to put in place more stringent nuclear security rules and to provide more numerous and effective guards.

UNSCR 1540 and nuclear security standards. UNSCR 1540 provides one potentially important tool in forging global nuclear security standards. This resolution, passed unanimously in April 2004, creates 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 all weapons of mass destruction and related materials).[45] 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 and 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. If broad agreement could be reached on the essential elements of an "appropriate effective" nuclear security system, that would, in effect become a legally binding global standard for nuclear security. 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).[46] 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.[47] The United States and other na-

[45] 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 18 June 2008).

[46] For an initial cut at defining the essential elements that must be included for nuclear security and accounting systems to meet the obligation to be "appropriate effective," see Matthew Bunn, "'Appropriate Effective' Nuclear Security and Accounting—What is It?", presentation to "'Appropriate Effective' Material Accounting and Physical Protection," (Joint Global Initiative/UNSCR 1540 Workshop, Nashville, Tennessee, 18 July 2008, available at http://belfercenter.ksg.harvard.edu/files/bunn-1540-appropriate-effective50.pdf as if 20 August 2008).

[47] Questions designed to clarify a country's compliance with this standard could include such items

tions agreeing to such a standard should 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.

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 Allison, *Nuclear Terrorism: The Ultimate Preventable Catastrophe*. 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 18 June 2008), pp. 31, 102. Other sources that could also be drawn on for insight in defining what should be included in 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 include 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 to comply fully with both of them and still not have a secure system.

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.

Strengthening IAEA nuclear security recommendations. As another pathway toward more effective international nuclear security standards, the next U.S. president should work closely with countries around the world to greatly strengthen the IAEA's recommendations for physical protection. While these are only recommendations, and the current version is quite vague, they are the closest thing to a real international standard for physical protection that exists, as most countries follow the recommendations, and recipients of nuclear material and technologies from the United States and some other exporters are required under bilateral nuclear supply agreements to provide physical protection comparable to the approaches the IAEA recommends.[48]

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 an-

[48] For a discussion of agreements including such requirements, see Bonnie Jenkins, "Establishing International Standards for Physical Protection of Nuclear Material," *Nonproliferation Review* Vol. 5, no. 3 (Spring-Summer 1998; available at http://cns.miis.edu/pubs/npr/vol05/53/jenkin53.pdf as of 18 June 2008).

other revision are now underway, and a group of states including the United States and many of its European allies have provided a set of proposals for the revision.[49]

The single most critical improvement the United States and other leading governments should seek to include in the new version is the same as the standard discussed above—that is, a minimum threat that nuclear stockpiles should be protected against. INFCIRC/225 Rev. 4 already recommends that states develop a "design basis threat" (DBT)—that is, a threat or set of threats that nuclear security systems should be designed to protect against—and make it an "essential element" of their physical protection systems.[50] But it does not specify anything about what the DBT should be or how exactly it should be used. As it stands, INFCIRC/225 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. A new revision should recommend that: (a) states should enact and enforce regulations requiring that all facilities and transport legs with Category I material have security systems in place able to provide a high probability of defeating the DBT;[51] and (b) that, while DBTs should vary from one state to another depending on the threat, at a minimum all Category I material everywhere should be defended at least against two small teams of well-armed and well-trained outsiders, 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. The minimum DBT just outlined corre-

[49] Interviews with IAEA officials, April 2008; NNSA officials, July 2007 and July 2008; and British official, July 2008. 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.

[50] 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).

[51] 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.

sponds roughly to the published version of the U.S. NRC DBT for theft.[52] 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;[53] 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. (The prospects for success in reaching agreement on such an approach would be enormously improved if political leaders from key countries had already agreed to protect their stockpiles against such threats and to help others do the same, as suggested above.)

In addition to a minimum DBT, a variety of other improvements should be made in INFCIRC/225. More measures are needed that focus 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. Consideration should be given either to adding requirements for material accounting and control—also key elements of integrated nuclear security systems—or developing a separate document on those topics. The revised INFCIRC/225 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 allowing 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.

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[52] 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 28 September 2005).

[53] 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.

New approaches to categorizing nuclear materials. One key element of building effective global nuclear security standards will be carefully thought-through approaches to defining what kinds of nuclear material pose the greatest dangers if stolen, and hence require the highest levels of protection. 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, in today's age of suicidal terrorists, it is clearly flat wrong to believe that that nuclear material emitting enough radiation to give thieves a dose of one Sievert per hour (1 Sv/hr) at one meter from the material is "self-protecting" from theft. This level of radiation would not be enough to even make the thieves feel ill, let alone disable them before they could complete their theft.[54] Recent analyses at U.S. laboratories suggest that the level of radiation would have to be 100 times higher to create doses big enough to physically disable thieves before they could complete their theft.[55] Yet the assumption that such material is "self-protecting" is enshrined in the IAEA recommendations, in the physical protection convention, and in national regulations in the United States and many other countries.[56]

This issue is a particular concern for irradiated HEU research reactor fuel. Unlike spent fuel from commercial power reactors—which is in massive, intensely radioactive fuel assemblies that could not be moved without special equipment—irradiated research reactor fuel elements are often small enough to simply be picked up and carried out to a waiting truck; often still contain very highly enriched uranium after use; and are not radioactive enough to deter suicidal thieves. Most of the world's irradiated HEU research reactor fuel has been cooling long enough that it is not self-protecting even by current standards, and virtually none of it could be considered self-protecting under more sensible standards. Irradiated HEU fuel also poses a proliferation and theft risk, and requires substantial security—which it does not receive in most countries today.

Unfortunately, making this change in how nuclear material should be categorized is likely to be difficult, since the notion that 1 Sv/hr at 1 meter is sufficient for material to be "self-protecting" is enshrined in the agreed text of the just-amended physical protection convention. At a minimum, the IAEA recommendation that states can reduce the security category assigned to nuclear material by one step (for ex-

[54] 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 (Washington, D.C.: U.S. Nuclear Regulatory Commission, 1982; available at http://www.sciencemadness.org/lanl1_a/lib-www/la-pubs/00307470.pdf as of 28 March 2008). For a useful discussion, see 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 16 May 2006).

[55] 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).

[56] Under the IAEA physical protection recommendations or the physical protection convention, "Category I" material—that is, material requiring the highest levels of security—can be downgraded to Category II if it is emitting radiation that would cause a dose rate of 1 Sv/hr at 1 meter. U.S. NRC regulations go further, exempting material above this threshold from virtually all security requirements.

ample, from Category I to Category II) if it is emitting radiation that would cause a dose rate of 1 Sv/hr at 1 meter could be modified 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.

Imposing tougher export requirements. U.S. law requires that nuclear exports not be "inimical to the common defense and security."[57] 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.[58] 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 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.[59] Seven 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. As a first step, the guidelines could be modified to require that countries receiving HEU or separated plutonium host an international peer review of their physical protection arrangements (such as from the IAEA's International Physical Protection Advisory Service), and address any issues the peer review identifies. Ultimately, as suggested above, effective security and accounting for weapons-usable nuclear material should become part of the "price of admission" for doing business in the international nuclear market.

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[57] *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 22 December 2006).

[58] Lyman, "Using Bilateral Mechanisms."

[59] 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 20 July 2005).

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. Vulnerable nuclear material anywhere is a threat to everyone, everywhere—so every country has a right to know how well other countries are fulfilling their nuclear security responsibilities. But creating mechanisms to provide that information 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 give other countries confidence that the security measures in place are fully effective.[60]

For those countries willing to accept international peer reviews of their security arrangements, IAEA-led peer reviews can be effective in building this 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.[61] 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 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.[62]

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.[63] In the case of U.S.-Russian cooperation, to build understanding of what was being tested and how, U.S. and Russian adversary teams used to test nuclear security systems might train together, and perhaps conduct tests together at some non-sensitive sites in each country. Then the remaining sites could be tested by purely national teams, using similar approaches and standards, and broad descriptions of the results could be provided to the other country.

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[60] 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.

[61] Norway was the first major developed state to request such an international peer review and encouraged 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).

[62] Allison, *Nuclear Terrorism: The Ultimate Preventable Catastrophe*, pp. 150-153.

[63] 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 percent of their inspections—and the targets for fiscal 2005 and fiscal 2006 were only to achieve 65 percent and 70 percent "effective" ratings, respectively.

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.

National regulations as steps toward global nuclear security standards. The purpose of a global nuclear security standard is to achieve actual results on the ground—effective and lasting security at each location, and for each transport operation, where nuclear weapons or the materials needed to make them exist worldwide. Inevitably, individual states will have to implement such standards, through the actions they take to achieve effective nuclear security, and in particular the nuclear security and accounting rules and regulations they put in place. Effective and effectively enforced regulations are critical to lasting nuclear security; as nuclear security measures cost money and bring in no revenue, most nuclear managers will only invest in those security measures their government tells them they have to have in place. If more and more countries—and particularly those where the highest risks of nuclear theft exist—put regulations in place requiring all facilities and transport operations with nuclear weapons or weapons-usable material to have security and accounting measures in place that would provide high confidence of protecting these stockpiles from demonstrated terrorist and criminal threats, this would represent major progress toward achieving the objective of a stringent global nuclear security standard—whether a global standard had yet been agreed to or not. The next U.S. president should drastically increase the priority placed on working to convince key countries around the world to put effective nuclear security and accounting regulations in place.

Build sustainability and security culture

It is critical not just to move quickly to put in place improved nuclear security measures where they are needed, but to put in place security that works, and that lasts. If the upgraded security equipment the United States is helping countries put in place is all broken and unused in five years, U.S. security objectives will not be accomplished. The Department of Energy (DOE) is working closely with Russia to try to ensure that Russia puts in place the resources, incentives, and organizations needed to sustain high levels of security for the long haul, and to build security cultures that will put an end to guards patrolling without ammunition or staff propping open security doors for convenience. But this is an extraordinarily difficult policy challenge. As recent events in the U.S. Air Force make clear, there is more to be done to ensure an adequate focus on maintaining high standards in handling nuclear weapons even in the United States (which almost certainly spends more on nuclear security than any other country in the world); attempting to strengthen security culture in foreign countries where the U.S. government's influence and understanding are far more limited is a much greater challenge. Such efforts need to be undertaken not just in Russia, but wherever nuclear weapons and the materials to make them exist. In particular, as most nuclear managers only invest in expensive security measures when the government tells them they have to, effective regulation is essential to effective and lasting security; a greatly increased focus on ensuring that countries around the world put in place and enforce effective nuclear security and accounting regulations will be critical to long-term success.

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 this case are discussed below.

Sustainability. Building on the progress NNSA and Rosatom have made toward implementing an agreed sustainability framework, the United States and other leading states should be working with countries and facilities 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, the next U.S. president should seek an explicit commitment from Russian President Dmitry Medvedev (or from Russian Prime Minister Vladimir 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.

  As sustainability is not only a Russia 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 ensuring resources for sustainability are more 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, and that each of these facilities and transport operations has 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 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. Russia has also submerged its nuclear regulatory agency within a much larger agency regulating a wide range of safety and environmental issues—and then submerged that larger agency within the Ministry of Natural Resources, weakening the power of the nuclear regulators and making it far more difficult for nuclear safety or security issues to percolate to the highest levels of government. The United States should consider whether there are actions it can take to help convince Russia to make its nuclear regulators again a powerful and independent agency reporting directly to the highest levels of the Russian government. 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.[64]

- *Consolidation.* Finally, consolidation, discussed above, is likely to be crucial to sustainability, making it possible to achieve higher security at lower cost. Russia, in particular, has over 200 buildings with weapons-usable nuclear material and scores of sites with nuclear warheads—an immense and expensive infrastructure to protect.

[64] Bunn, "Incentives for Nuclear Security."

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 really 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 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, which are indirect indicators of security culture.

Beyond Nuclear Security

This report has focused on improved security measures to stop nuclear weapons or the materials needed to make them from being stolen—for that is the critical chokepoint on the terrorist pathway to the bomb. If they cannot get the material, they cannot make a bomb.

While nuclear security efforts should continue to receive the highest priority in preventing nuclear terrorism, they cannot be expected to be perfect, and they should not be the only part of the effort. An integrated system of complementary efforts is needed, that goes beyond securing nuclear weapons and materials to include disrupting terrorist nuclear plots, interdicting nuclear smuggling, deterring states from helping terrorists achieve their nuclear ambitions, responding to nuclear emergencies, impeding terrorist recruitment of nuclear know-how, reducing nuclear stockpiles, ending the accumulation of HEU and plutonium for weapons, and monitoring reductions.[65]

Disrupt: counter-terrorism efforts focused on nuclear risks

The next U.S. president should work with other countries to build an intense international focus on stopping the other elements of a nuclear plot—the recruiting, fundraising, equipment purchases, and more that would inevitably be required. Because of the complexity of a nuclear effort, these would offer a bigger and more detectable profile than many other terrorist conspiracies—although, as U.S. intelligence officials have pointed out, the observable "footprint" of a nuclear plot might be no bigger than that of the 9/11 plot.[66] The best chances to stop such a plot lie not in exotic new detection technologies but in a broad counter-terrorist effort, ranging from intelligence and other operations to target high-capability terrorist groups to addressing the anti-American hatred that makes recruiting and fund-

[65] For a recent discussion that focuses on such an overall system approach, with only a brief discussion of improved security for nuclear stockpiles, see Michael Levi, *On Nuclear Terrorism* (Cambridge, Mass.: Harvard University Press, 2007).

[66] See Rolf Mowatt-Larssen, director, DOE Office of Intelligence and Counterintelligence, U.S. Senate, Committee on Homeland Security and Governmental Affairs, 2 April 2008, available at http://hsgac.senate.gov/public/_files/040208MowattLarssen.pdf as of 11 November 2008.

raising easier, and makes it more difficult for other governments to cooperate with the United States.

The United States and other leading governments should continue and expand their efforts to identify 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,[67] 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.[68]

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 in achieving 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

[67] 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.

[68] 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).

zones," if successful, would also help reduce the risk of nuclear terrorism.[69]

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. In Pakistan in particular, working with the new civilian government to build a joint approach to the extremists in the tribal areas that combines military, intelligence, or police action against particular key individuals with new efforts to convince the bulk of the population to turn against violent extremism—as occurred with the Sunni Awakening's rejection of al-Qaeda in Iraq—could substantially reduce both the capabilities terrorists might bring to bear to try to seize nuclear weapons or materials in Pakistan, and the terrorists' ability to sustain long-term efforts such as a nuclear program without being disrupted.

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.[70] 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, the United States should work with governments and non-government organizations in the Islamic world to seek to broaden the discussion regarding the moral illegitimacy of mass violence

[69] 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, *The Worldwide Threat 2004: Challenges in a Changing Global Context*, U.S. Senate, 108th Congress, 2nd Session, 9 March 2004 available at https://www.cia.gov/news-information/speeches-testimony/2004/tenet_testimony_03092004.html as of 11 November 2008.

[70] The effort to "diminish the conditions" that lead to terrorism is one of the key elements of U.S. counter-terrorism 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).

that is already underway among violent Islamic extremists themselves, as discussed in Chapter 1. Building a consensus among most Islamic people that slaughter on a nuclear scale is counter to 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.

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 next U.S. president must work with other countries and with the U.S. Congress to modify U.S. approaches to interdicting nuclear smuggling, to get the greatest reduction in the smuggler's chances of succeeding with the least investment of funds. Rather than focusing immense resources—both of money and of diplomatic capital—on ensuring that 100 percent of shipping containers are scanned for radiation before they enter the United States, the United States should focus on an overall system designed to cope with intelligent adversaries who are likely to search for ways to go around or counter international efforts to stop them, and to take advantage of the smugglers' weaknesses.[71]

The smugglers' greatest weaknesses are: (a) they must deal with a number of human beings along the transport chain, any one of whom might decide to inform on them; and (b) the buyers and the sellers have little way of knowing that the other party is genuine, and not a scam artist or government agent. Indeed, most of the past successes in seizing stolen nuclear material have come from conspirators informing on each other and from good police and intelligence work, not from radiation detectors.[72] Effective intelligence and police operations can make both of

[71] For a discussion of such a systems approach, see Matthew Bunn, "Designing a Multi-Layered Defense against Nuclear Terror," paper presented at The Homeland Security Advisory Council Task Force on Weapons of Mass Effect, Washington, D.C., 13 June 2005 (available at http://belfercenter.ksg.harvard.edu/publication/17189/designing_a_multilayered_defense_against_nuclear_terror.html as of 8 July 2008). For a very pointed imagined discussion among would-be nuclear terrorists concerning the weaknesses of international efforts to stop them, see William C Potter, "Nuclear Terrorism and the Global Politics of Civilian HEU Elimination," *Nonproliferation Review* Vol. 15, no. 2 (July 2008). For a discussion in particular of the follies of installing expensive and easily observable detectors at border crossings that smugglers can easily bypass, see William Langeweische, *The Atomic Bazaar: The Rise of the Nuclear Poor* (New York: Farrar, Straus, Giroux, 2007).

[72] For a discussion of the most recent significant HEU case, in Georgia in 2006, which resulted from organized crime elements informing Georgian intelligence of a Russian looking for a buyer for stolen HEU, and the Georgians then putting together a sting operation, see Michael Bronner, "100 Grams (And Counting): Notes From the Nuclear Underworld" (Cambridge, Mass.: Project on Managing the Atom, Harvard University, June 2008, available at http://belfercenter.ksg.harvard.edu/files/Bronner percent20Booklet percent20Final.pdf) as of 30 July 2008.

these weaknesses worse, enormously complicating the smugglers' job. The next U.S. president should work with other countries around the world to intensify police and intelligence cooperation focused on stopping nuclear smuggling; 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. This cooperation should include: (a) 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;[73] and (b) well-publicized rewards and tiplines to encourage informers to report on such plots. 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.[74]

[73] 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.

[74] William Langeweische, "How to Get a Nuclear Bomb," *Atlantic Monthly* Vol. 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.

Building up states' capacity to detect and investigate such plots, and the legal infrastructure to prosecute them, is also important. The next U.S. president should work with states around the world to ensure that all potential source states and likely transit states have: (a) units of their national police forces trained and equipped to deal with nuclear smuggling cases, and other law enforcement personnel should be trained to call in those units as needed;[75] (b) laws on the books and effectively enforced, making any participation in real or attempted theft or smuggling of nuclear weapons or weapons-usable materials, or nuclear terrorism, crimes with penalties comparable to those for murder or treason; and (c) a commitment to catching and prosecuting those involved in such transfers; and (d) standard operating procedures, routinely exercised, to deal with materials that may be detected or intercepted.

The Proliferation Security Initiative (PSI) is often portrayed as a key part of the effort to stop smuggling of nuclear weapons, materials, and technologies. But it is likely to be much more useful in stopping shipments of large, readily detectable items such as crates of centrifuge components or ballistic missiles than in stopping transfers of nuclear materials that can fit in a suitcase. The initiative may help in focusing some countries' attention on putting needed border controls and anti-smuggling legislation in place, but its

[75] 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).

overall contribution to reducing the risk of nuclear material smuggling is likely to be small.

Radiation detection, judiciously applied, should be one part of this overall effort to decrease nuclear smugglers' chances of success. But insisting on scanning every shipping container, as Congress set as the goal for 2012—when nuclear smugglers have many other pathways to use, and the scanners available would not be able to detect HEU metal with even modest shielding—is not the best approach.[76] Given the limitations of the technology and the myriad routes smugglers might use, radiation detection will always be a limited tool, and must not be relied on as the centerpiece of efforts to stop nuclear smuggling. Ultimately, as intelligence and border controls are strengthened, governments will be more likely to catch a terrorist crossing a border than to detect the nuclear material he or she may be carrying.

Given that reality, the next U.S. president should instruct his experts to outline an integrated system that looks not just at installing radiation detectors but at what options adversaries would have to defeat the system—by choosing other routes, bribing officials to get past detectors, hiding nuclear material in difficult-to-search cargoes, and other means—and what options the defense might have for countering those adversary tactics.[77] This system should be designed to achieve a greater reduction in the nuclear smugglers' overall chances of success than the current 100 percent scanning of cargo containers mandate, at lower cost in money, interference with normal flows of trade, and diplomatic capital expended. Based on such an analysis, the next U.S. president should then work with the Congress and other leading governments to modify existing approaches and legislation, pulling existing efforts into a prioritized 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.

Prevent and deter: reducing the risk of nuclear transfers to terrorists by states

As discussed in Chapter 1, conscious state decisions to transfer nuclear weapons or materials to terrorists are a small part of the overall risk of nuclear terrorism; hostile dictators focused on preserving their regimes are highly unlikely to hand over the greatest power they have ever acquired to groups they cannot control, in ways that might provoke retaliation that would destroy their regimes forever. Nevertheless, this risk is not zero, and the next U.S. president should take steps to reduce it further.

First, the next U.S. president must continue the ongoing engagement with North Korea and abandon the self-defeating posture of refusing to enter into negotiations with Iran until Iran meets U.S. conditions—which simply allows Iran to pursue

[76] Indeed, cargo containers in general may not be an attractive smuggling method for a nuclear bomb. It seems unlikely that a terrorist group, after investing immense organizational resources into getting the materials for a nuclear weapon and fashioning them into a working bomb (or ready-to-assemble pieces) would then choose a transport mode in which the bomb or its components would be completely out of the group's control for days or weeks, and potentially subject to unexpected inspection and seizure.

[77] For a discussion of such approaches, see Michael Levi, *On Nuclear Terrorism*.

its nuclear program unfettered and blame the lack of progress on the United States. He must work 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* national 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, and just under a kilogram in a new Miniature Neutron Source Reactor provided by China.[78]) 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.[79]

Second, the next U.S. president should take steps to strengthen the global effort to stem the spread of nuclear weapons more broadly, reducing the chances that other states might someday gain nuclear weapons that might fall into terrorist hands. From strengthening international inspections to stopping black-market nuclear networks to building new international approaches to the nuclear fuel cycle to reducing the incentives for states to want nuclear weapons, a broad range of steps can and should be taken to bolster the nonproliferation regime.[80] There will be little hope of gaining international political support for such steps—all of which involve more constraints and inconveniences for the non-nuclear-weapon states—if the United States and the other nuclear weapon states are not seen as taking clear action to fulfill their obligation to take good-faith steps toward nuclear disarmament. In particular, with the 2005 Nonproliferation Treaty Review Conference having collapsed in discord—in significant part over the U.S. refusal to even discuss the disarmament steps all parties had agreed to at the previous meeting—the next U.S. President must take quick action to establish a more positive and constructive atmosphere going into the 2010 review.

Third, 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. This should include both

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[78] The U.S.-provided Tehran 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).

[79] See, for example, Ray Takeyh, "Take Threats Off the Table Before Sitting With Iran," *Boston Globe*, 3 May 2007 available at http://www.boston.com/news/globe/editorial_opinion/oped/articles/2007/05/03/taking_threats_off_the_table_before_sitting_with_iran/ as of 11 November 2008.

[80] For an overview of steps to prevent proliferation, see Weapons of Mass Destruction Commission, Hans Blix, chairman, *Weapons of Terror: Freeing the World of Nuclear, Biological, and Chemical Arms* (Stockholm: Weapons of Mass Destruction Commission, 2006, available at http://www.wmdcommission.org/files/Weapons_of_Terror.pdf as of 25 August 2008). See also Commission of Eminent Persons, *Reinforcing the Global Nuclear Order for Peace and Prosperity: The Role of the IAEA to 2020 and Beyond* (Vienna: International Atomic Energy Agency, May 2008).

increased funding for R&D (currently so much of the funding is staying at the Department of Homeland Security that U.S. laboratories working on forensics of seized materials have had to lay off some of their staff) and expanded efforts to put together an international database of material characteristics. Policymakers should understand, however, that nuclear material has no DNA that can provide an absolute match: nuclear forensics will provide a useful but limited source of information to combine with other police and intelligence information, but will rarely allow us to know where material came from by itself.

Fourth, the United States and other leading governments should 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.[81] (Fortunately for the world, by the time of the war, Saddam's regime had no such weapons and the issue did not arise.)

[81] 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).

Fifth, the United States and other leading states should avoid actions that would increase the probability of state collapse 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.[82] State failure in Pakistan would also pose an immense risk of nuclear assets falling into the hands of jihadi terrorists.

Sixth, 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, attempting similar efforts with neighbors of Iran and Pakistan[83] (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 PSI, discussed above. As just discussed, however, there

[82] 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.

[83] 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.

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 Teams (NEST, formerly the Nuclear Emergency Search Team) are 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.[84] 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 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 next U.S. president 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.

Impede: impeding terrorist recruitment of nuclear personnel

Al-Qaeda has repeatedly attempted to recruit nuclear experts. While people with classified knowledge of nuclear weapons design and manufacture would not be essential to a terrorist nuclear bomb program, they would be helpful. Indeed, al-Qaeda second-in-command Ayman al-Zawahiri appears to have recognized much the same with respect to biological weapons, telling Mohammed Atef that, while the group should attempt to develop such weapons on its own, at the same time, it should attempt to recruit specialists with prior knowledge, as that would be "the fastest, safest, and cheapest way" to get a biological arsenal.[85] The

[84] For a summary of NEST and its history, see, for example, Jeffrey T. Richelson, "Defusing Nuclear Terror," *Bulletin of the Atomic Scientists* Vol. 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 Steve Coll, "The Unthinkable: Can the United States be made safe from nuclear terrorism?" *The New Yorker*, (12 March 2007 available at http://www.newyorker.com/reporting/2007/03/12/070312fa_fact_coll as of 11 November 2008).

[85] See Alan Cullison, "Inside Al-Qaeda's Hard Drive: Budget Squabbles, Baby Pictures, Office Rivalries—and the Path to 9/11," *The Atlantic, (*September 2004, available at http://www.theatlantic.com/doc/200409/cullison as of 25 August 2008).

next U.S. president should take additional steps to make such recruitment as difficult as possible.

Most of the international effort in this area to date has focused on stabilizing employment for scientists and engineers with expertise in weapons of mass destruction—originally in Russia and the former Soviet Union, and now to a limited degree in Iraq, Libya, and elsewhere as well. Despite the recent improvements in the Russian economy, the U.S.-funded scientist-redirection programs continue to offer benefits to U.S. security worth the modest investments the U.S. government makes in them. These programs have built valuable collaborations between scientists and companies in the former Soviet Union and the West, providing a window for exchange of ideas and perspectives, and for understanding the structure of the scientific enterprise in these countries. Moreover, the limited data available suggests 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.[86] Contrary to newspaper reports,[87] the fact that some institutes that have received NNSA funds also have some experts who have worked on a safeguarded power reactor in Iran does not in any way mean that NNSA programs have somehow contributed to Iran's nuclear program. Moreover, while a substantial fraction of the long-term jobs these programs have created have gone to people who are not weapons scientists,[88] that is hardly a surprise. It is hard to think of a new business in the United States or elsewhere that has former weapons scientists for 100 percent, or even 80 percent, of its employees.[89]

At the same time, there is clearly a need to reform these efforts to match today's threats. The dramatically changed Russian economy creates a very different threat environment. The experience of the A.Q. Khan network suggests that dramatic leakage of proliferation-sensitive expertise may come from well-to-do experts motivated by ideology and greed, and not only from desperate, underemployed experts. For a terrorist group, a physicist skilled in modeling the most advanced weapons designs—the kind of person who has often been the focus of these programs in the past—may be much less interesting than a machinist experienced in making bomb parts from HEU metal, or a guard in a position to let thieves into a building undetected. Experts who are no longer employed by weapons institutes, but whose pensions may be inadequate or whose private ventures may have failed, could pose particularly high risks, but they are not addressed by current programs focused on redirecting weapons expertise.

86 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).

87 Matthew Wald, "U.S.-Backed Russian Institutes Help Iran Build Reactor," *New York Times*, (7 February 2008 available at http://www.nytimes.com/2008/02/07/washington/07nuke.html as of 11 November 2008).

88 See U.S. Government Accountability Office, *Nuclear Nonproliferation: DOE's Program to Assist Weapons Scientists in Russia and Other Countries Needs to be Reassessed* (Washington, D.C.: December 2007).

89 Clearly, however NNSA should stop counting 100 percent of the long-term jobs created by these efforts in its count of jobs provided for former weapons scientists.

The next U.S. president 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.[90] 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).[91] The United States is not likely to have either the access or the resources to do everything itself. The solution is likely to require working in partnership with Russia and other countries, to get them to do most of what needs to be done—while at least maintaining funding for existing U.S.-funded programs for a few more years.

At the same time, the next U.S. president should work with key countries such as Russia and Pakistan to strengthen control of classified nuclear information and to ensure that they monitor contacts and behavior of all individuals with key nuclear secrets. The United States should also work with other countries to monitor and stop recruitment attempts at key sites, such as physics and nuclear engineering departments in countries with substantial Islamic extremist communities. If successful, efforts to build an ever-larger consensus that mass slaughter on a nuclear scale is unacceptable under Islamic law or under other religious traditions, discussed above, could play a major role in making it more difficult for terrorists to recruit nuclear experts.

Reduce: reducing stockpiles and ending production

In addition to securing nuclear material at sites and removing material from especially vulnerable sites, the next U.S. president should also take steps to reduce stockpiles of nuclear weapons and weap-

[90] 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.

[91] 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).

ons-usable nuclear material and avoid the accumulation of ever-larger stockpiles. But the effect of these steps in reducing nuclear theft risks should not be exaggerated. 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 do little to reduce the risk of nuclear theft (however worthwhile they may be for other reasons) unless they are targeted toward eliminating stocks entirely from as many buildings and sites as possible.

The United States, Russia, and other nuclear weapon states should join in an effort to radically reduce their nuclear weapon stockpiles and their roles and readiness, verifiably dismantling many thousands of nuclear weapons and placing the fissile material they contain in secure, monitored storage until it can be safely and securely destroyed. Very deep reductions in nuclear stockpiles, if properly managed, would reduce the risks of nuclear theft—and could greatly improve the chances of gaining international support for other nonproliferation steps that could also reduce the long-term dangers of nuclear theft.[92]

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 stored at remote, difficult-to-defend storage sites.[93] 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[94]—and place them in

[92] See, for example, discussion in Matthew Bunn, "Securing Nuclear Stockpiles Worldwide," in *Reykjavik Revisited: Steps Toward a World Free of Nuclear Weapons,* (Stanford, CA: Hoover Press/NTI, 2008), pp. 47-50.

[93] 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).

[94] 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

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.[95]

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.[96] Russia has made clear that it will not renew the existing agreement (which 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—and there are a variety of opportunities for the United States or other countries to offer increased incentives for Russia to blend down additional HEU.[97] 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.[98]

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

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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.

[95] 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, Stockholm 2005 (available at http://www.wmdcommission.org/files/No8.pdf as of 18 April 2005).

[96] For a discussion, see Matthew Bunn and Anatoli Diakov, "Disposition of Excess Highly Enriched Uranium," in *Global Fissile Materials Report 2007* (Princeton, NJ: International Panel on Fissile Materials, October 2007), pp. 24-32.

[97] For a discussion of a variety of possible incentives that might convince Russia that it was in its interests to blend down large additional stocks of HEU, see Matthew Bunn, "Expanded and Accelerated HEU Downblending: Designing Options to Serve the Interests of All Parties," in *Proceedings of the Institute for Nuclear Materials Management 49th Annual Meeting,* Nashville, Tenn., 14-17 July 2008 (Northbrook, IL: INMM, forthcoming).

[98] For an earlier discussion of market impact mitigation options, 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).

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.[99] In September 2007, U.S. Secretary of Energy Samuel Bodman declared an additional nine tons of U.S. excess weapons plutonium excess and available for disposition. This is a valuable first step, but still leaves enough plutonium remaining to build some 9,000 nuclear warheads.[100] The next U.S. president should launch a joint program with Russia to reduce total U.S. and Russian stockpiles of nuclear weapons to something in the range of 1,000 weapons, and to place all plutonium and HEU beyond the stocks needed to support these low, agreed warhead stockpiles (and modest stocks for other military missions, such as naval fuel) in secure, monitored storage pending disposition.

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.[101] The next U.S. president should reverse the Bush administration's misguided opposition to a verified fissile cutoff, and lead work with other governments to overcome the obstacles to negotiating such a treaty[102]—including the possibility of undertaking negotiations outside of the Conference on Disarmament if that body continues to be unable to move forward.

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. As discussed in Chapter 2, the two reactors at Seversk shut down in the first half of 2008, leaving only the reactor at Zheleznogorsk, which is expected to shut in 2010. This shutdown will bring to an end both a large quantity of plutonium reprocessing and a large quantity of HEU fuel element fabrication and transportation every year, reducing theft risks. 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.

[99] See discussion in Matthew Bunn and Anatoli Diakov, "Disposition of Excess Plutonium," in *Global Fissile Materials Report 2007* (Princeton, NJ: International Panel on Fissile Materials, October 2007), pp. 33-42.

[100] See, for example, Gregory Webb, "U.S. to Convert Weapons Plutonium Into Fuel," *Global Security Newswire, (*17 September 2007 available at http://gsn.nti.org/gsn/GSN_20070917_FF5E6A7B.php as of 11 November 2008).

[101] I am grateful to William Walker for making this point to me. Personal communication, March 2003.

[102] For a discussion, see, for example, International Panel on Fissile Materials, " A Fissile Material Cutoff Treaty and its Verification," Geneva, 2 May 2008, available at http://www.fissilematerials.org/ipfm/site_down/ipfmbriefing080502.pdf as of 25 August 2008.

Monitor: monitoring nuclear stockpiles and reductions

As discussed in Chapter 2, declarations and monitoring of nuclear stockpiles can also be an important tool to reduce the risk of nuclear terrorism. By opening sites to foreign visitors, such measures ease the security obstacles to nuclear security cooperation; they can motivate states to fix obvious security and accounting problems to avoid embarrassment; and, as just noted, they create a multinational discipline on the quality of accounting measures that is not present when no such measures are in place and states are left to determine for themselves what control and accounting measures to take.[103] Moreover, such measures are an essential part of moving toward deep reductions in nuclear arms, which would have their own benefits for reducing the risk of nuclear terrorism, as just discussed.

The next U.S. president should work with Russia to revive efforts to put in place a system of data exchanges, reciprocal visits, and monitoring that would build confidence in the size and security of each side's nuclear stockpile, lay the groundwork for deep reductions in nuclear arms, and confirm agreed reductions in nuclear warhead and fissile material stockpiles.[104]

In particular, the next U.S. president should seek Russian agreement, before the 2010 NPT review, that each country will place large quantities of excess fissile material under IAEA monitoring, reviving the Trilateral Initiative, which developed legal agreements, procedures, and technologies to allow the IAEA to monitor such material even if it is still in classified forms, without revealing classified information.[105]

Leadership and Commitment

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 and creative leadership at many levels—at the highest levels of key governments around the world; in nuclear ministries and regulatory agencies; among intelligence, police, customs, and border control agencies; and at every nuclear facility or transport organization that handles nuclear weapons, plutonium, or HEU.

For better or for worse, 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 sys-

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[103] For a discussion of this connection, see, for example, 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 28 March 2008), pp. 147-148.

[104] For an excellent account of what such a transparency regime might look like, and its potential benefits, see 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 http://books.nap.edu/catalog/11265.html as of 18 June 2008). See also Nicholas Zarimpas, ed., *Transparency in Nuclear Warheads and Materials: The Political and Technical Dimensions* (Oxford: Oxford University Press for the Stockholm International Peace Research Institute, 2003).

[105] See, for example, Thomas E. Shea, "The Trilateral Initiative: A Model for the Future?" *Arms Control Today, (*May 2008 available at http://www.armscontrol.org/act/2008_05/PersboShea.asp%2523Sidebar1 as of 11 November 2008).

tems-engineering approaches to nuclear material protection, control, and accounting (MPC&A).

The next U.S. president must exert sustained leadership himself—and put in place the institutions and approaches that will increase the chance that others will see the urgency of the threat and exert similar leadership themselves.

Building the sense of urgency and commitment worldwide

The fundamental key to success in preventing nuclear terrorism is 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 money—something many of them do *not* believe today. If they come to feel that sense of urgency, they will take the needed actions to prevent nuclear terrorism; if they remain complacent, they will not. Some of the critical work of building this sense of urgency is already being done, especially in the context of the Global Initiative to Combat Nuclear Terrorism and in discussions between key U.S. intelligence officials and their foreign counterparts. But much more needs to be done.

The next U.S. president should work with other countries to take several steps to build the needed sense of urgency and commitment, including:

- **Joint threat briefings.** Upcoming summits and other high-level meetings with 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.
- **Intelligence-agency discussions.** In many countries, the political leadership gets much of its information about national security threats from its intelligence agencies. It is therefore extremely important to convince the intelligence agencies in key countries that nuclear terrorism is a serious and urgent threat—and that plausible actions, taken now, could reduce the risk substantially. Some U.S. agencies—particularly DOE intelligence—are already actively working with foreign intelligence services to make this case, and to build cooperation against the threat. The next U.S. president should direct U.S. intelligence agencies to continue and expand this effort.
- **Nuclear terrorism exercises.** Building on the exercise program that has begun in the Global Initiative to Combat Nuclear Terrorism, the United States and other leading countries should organize a series of exercises with senior policymakers from key states. These exercises should have scenarios focused on theft of nuclear material, the realistic possibility that terrorists could construct a crude nuclear bomb if they got enough HEU or plutonium, just how difficult it would be to stop them once they had the material, and how much *all* countries would be affected if a terrorist nuclear bomb went off. 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—such as a well-placed insider, or two teams of well-armed, well-trained attackers. (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 particular threats to defend against. WINS could be a forum for creating one version of such a threat-incident database. In the case of safety, rather than security, reactors report each safety-related incident to groups such as the Institute of Nuclear Power Operations (the U.S. branch of the World Association of Nuclear Operators), and these groups analyze the incidents and distribute lessons learned about how to prevent similar incidents in the future to each member facility—and then carry out peer reviews to assess how well each facility has implemented the lessons learned.[106]

Putting someone in charge

The steps needed to prevent nuclear terrorism cut across multiple cabinet departments, and require cooperation in highly sensitive areas with countries across the globe. They will require sustained effort, day-in and day-out, from the highest levels of the U.S. government—and other governments. Yet today, there is no one in the U.S. government with full-time responsibility for all of the disparate efforts to prevent nuclear terrorism. Last year, Congress acted to create a senior, full-time position in the White House solely focused on weapons of mass destruction nonproliferation and terrorism. Unfortunately, President Bush has not filled this position.

The president who takes office in January 2009 should appoint a senior White House official who has the president's ear—probably a Deputy National Security Advisor, though the specific title would depend on the person and the structure of the NSC—whose sole responsibility will be to wake up every morning thinking "what can we do today to prevent a nuclear terrorist attack?" 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. While issues such as North Korea, Iran, and Iraq push themselves to the front pages, a full-time White House official for preventing nuclear terrorism can help ensure that this issue does not

[106] See Rees, *Hostages of Each Other: The Transformation of Nuclear Safety since Three Mile Island*.

get pushed to the back burner. The next U.S. president should also lean on Russia and other key countries to appoint similar officials with this critical responsibility.

Many people—especially in operational agencies who resist having more White House control—argue that a full-time White House official is not needed. But few presidents have seen it that way when it came to issues they cared about. Again and again, when presidents have wanted sustained priority focused on a particular issue, they have appointed someone they trust to oversee the issue full-time. President Bush himself, despite creating a Department of Homeland Security, 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 eliminate the disputes between the departments and agencies that continue to play essential roles. Similarly, President Bush decided he needed to have a Deputy National Security Advisor focused full-time on integrating and pushing forward the military, diplomatic, and nation-building strands of his administration's approach to Iraq and Afghanistan. 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, and was completed in 2003. But because 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).[107] These were three years that were taking place after the 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. By early 2008, the transparency measures were still not resolved, loading plutonium into the facility was proceeding only slowly, and most of the facility remained empty. 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 urgent steps to secure nuclear stockpiles around the world—has been a focus of any but

[107] 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 Its Nuclear Arsenal Is an Uphill Battle," *The Wall Street Journal*, 26 September 2005.

two of President Bush's meetings with foreign leaders, or 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 campaign 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. 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.[108]

Developing a comprehensive, prioritized plan

Today, the U.S. government has dozens of programs focused on pieces of the problem of preventing nuclear terrorism, each of which has its own plan for its own piece—and no comprehensive, prioritized plan. There is no systematic mechanism in place for identifying the top priorities or where there may be gaps, overlaps, or inefficiencies. One of the first priorities of the new single leader must be to put in place a comprehensive, prioritized plan. This plan should include 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 and quickly identifying obstacles to progress and possible ways to resolve them along with 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

[108] 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 8 July 2008). 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.

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.

Assigning adequate resources

The President and Congress should act to ensure that major efforts to reduce the risk of nuclear terrorism have the resources to move forward as fast as technology and international cooperation will allow.

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. But as described in Chapter 4, some programs could be significantly strengthened or accelerated with an infusion of additional funds. 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 to make them out of terrorist hands that the 9/11 Commission recommended.[109]

In particular, since new opportunities to improve nuclear security sometimes arise unexpectedly, and difficult-to-plan incentives are sometimes required to convince facilities to give up their HEU or convert a research reactor, Congress should consider an appropriation in the range of $500 million, to be available until expended, that can be spent flexibly on high-priority actions to reduce the risk of nuclear theft as they arise. Such a flexible pool of funds would give the new administration the ability to hit the ground running with an expanded and accelerated effort.

In some cases, new resources will also be needed beyond traditional national security agencies. The Nuclear Regulatory Commission (NRC), for example, currently has a very limited budget for international cooperation, yet improving national regulations for nuclear security is likely to be a key element of an effective global strategy. Similarly, there may well be cases where getting an agreement to shut down a research reactor will require assistance from the U.S. Agency for International Development (USAID) to help redirect institute personnel. The senior official described above will need the authority to work with these agencies, the Office of Management and Budget, and the Congress to ensure that all the relevant agencies have the resources to take the actions needed to prevent nuclear terrorism.

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, and 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

[109] 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).

of fiscal year (FY) 2006, and at that time the remaining upgrades planned were expected to cost just under an additional $100 million.[110] 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.[111] 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 estimate of costs. 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 analysis 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, U.S. intelligence in this area at that time was weak.[112]

Since then, 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 destruction, it will always be very difficult to know what individual terrorist groups may be doing relating to weapons of mass destruction.[113]

Focusing intelligence resources on supporting the highest-leverage policy option for reducing the risk of nuclear terrorism—improving security for vulnerable stockpiles—offers considerable promise. President Bush has established the Nuclear Materials Information Program (NMIP), designed to collect and analyze intended to compile key information on nuclear stockpiles, their security, and the

[110] U.S. Congress, Government Accountability 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 7 July 2008), pp. 12, 16.

[111] 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.

[112] 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 25 June 2008).

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

threats to them around the world. The next U.S. president should ensure that this effort integrates the full spectrum of information policymakers need to make nuclear security programs effective. 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? 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 priorities, 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.

In collecting and analyzing this information, 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."

In addition to intelligence support, these efforts need support fertilization from non-government ideas and analysis. Yet U.S. nonproliferation programs rely much less on work by universities and non-government organizations than many other parts of the U.S. government do. The U.S. Department of Homeland Security, for example, despite being a relatively new department operating in areas that are often shrouded in secrecy, has established several "centers of excellence" for university-based analysis of particular categories of homeland security problems, along with other programs focused on bringing in academic expertise to contribute to improving homeland security. The next U.S. president should act to ensure that programs to counter nuclear terrorism take similar steps. Each of the largest and most important nonproliferation programs should have a standing advisory group of outside experts regularly reviewing its efforts and suggesting ideas for improvement. In addition, NNSA should make a small investment in non-government analyses of key proliferation risks and how they might be reduced more effectively.

Getting the United States' Own House in Order

The most urgent nuclear security vulnerabilities are largely in other countries. But there is much more than can and should be done within the United States itself as well, as incidents such as the inadvertent flight of six nuclear weapons to Barksdale last year make clear. Convincing foreign countries to reduce and consolidate nuclear stockpiles, to put stringent nuclear security measures in place, or to convert their research reactors from HEU to LEU fuel will be far more difficult if the United States is not doing the same at home. DOE should continue providing funding to convert U.S. research reactors to LEU. Congress should provide funding for DOE to help HEU-fueled research reactors, or research reactors that pose serious sabotage risks, to upgrade security voluntarily. At the same time, Congress should direct the Nuclear Regulatory Commission (NRC) to phase out the exemption from most security rules for HEU that research reactors now enjoy, and provide funding for DOE to help these reactors pay the costs of effective security. Congress should also insist that NRC revise its rule exempting HEU that is radioactive enough to cause doses of more than one Sievert per hour at one meter from almost all security requirements, as recent studies make clear that this level of radiation would pose little deterrent to theft by determined terrorists. The NRC's requirements for protection of potential nuclear bomb material should be strengthened to bring them roughly in line with DOE's rules for identical material (particularly since the NRC-regulated facilities handling this material are doing so almost entirely on contract to DOE in any case, so DOE will end up paying the costs of security as it does at its own sites). Congress should also provide incentives to convert HEU medical isotope production to LEU, without in any way interfering with supplies, by imposing a roughly 30 percent tax on all medical isotopes made with HEU, with the funds used to help producers convert to LEU. This would give producers a strong financial incentive to convert, and since the isotopes are a tiny fraction of the costs of the medical procedures that use them, would not significantly affect the costs or availability of these life-saving procedures.

Finally, while the risk of nuclear terrorism can and must be reduced dramatically, it cannot be eliminated. Hence, more must be done to prepare for the ghastly aftermath of a terrorist nuclear attack, should prevention efforts fail. The United States should put in place:

- a rapid ability to assess which people are in the greatest danger and to tell them what they can do to protect themselves;
- better capabilities to communicate to everyone, when TV, radio, and cell phones in the affected area may not be functioning properly;
- better public communication plans for the critical minutes and hours after such an awful attack;
- improved measures to encourage and help people to take simple steps to get themselves and their families ready for emergencies;
- strengthened capabilities—including making use of the military's capabilities—to treat many thousands of injured people;
- better plans to keep our government and economy functioning;[114] and
- new plans for what steps will be taken to prevent another attack.

Realistically, there is no way to be fully prepared for a no-warning catastrophe on the scale of a nuclear blast. But many of these steps would help us respond to any catastrophe, natural or man-made, and would pay off even if our efforts to prevent a terrorist nuclear attack succeeded.[115]

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[114] In particular, Congress has not yet acted to put a plan in place for reconstituting itself should most members of Congress be killed in a nuclear attack. For a discussion of the importance of such a plan, and specific recommendations, see Continuity of Government Commission, *Preserving Our Institutions: The Continuity of Congress* (Washington: American Enterprise Institute and Brookings Institution, May 2003).

[115] For an especially useful recent discussion, see Ashton B. Carter, Michael M. May, and William J.

Conclusion

The next president must make preventing nuclear terrorism a top priority of U.S. national security policy—not just in words, but in sustained action.[116] Coping with this danger will pose a fundamental challenge. But at the same time, the next U.S. president has an historic opportunity—an opportunity to reduce the risk of nuclear terrorism to a small fraction of its present level during his first term. Accomplishing that will not be easy—but with a sensible strategy, adequate resources, and sustained leadership, it can be done. The security of the United States and the world demand no less.

Perry, *The Day After: Action in the 24 Hours Following a Nuclear Blast in an American City* (Cambridge, MA: Preventive Defense Project, Harvard and Stanford Universities, May 2007, available as of 28 March 2008 at http://belfercenter.ksg.harvard.edu/files/dayafterworkshopreport_may2007.pdf)

[116] For a discussion of lack of real, as opposed to rhetorical, priority from the highest levels of the U.S. government, see Charles B. Curtis, President, Nuclear Threat Initiative, "Preventing Nuclear Terrorism: Our Highest Priority – Isn't," Speech at the National Defense University Foundation, 21 May 2008 available at http://www.nti.org/c_press/speech_curtis_NDU_052108.pdf, as of 11 November 2008.

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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 and book-length 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*.

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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) is the Harvard Kennedy School's primary group focused on reducing the risk of nuclear and radiological terrorism, stopping nuclear proliferation and reducing nuclear arsenals, lowering the barriers to safe and secure nuclear-energy use, and addressing the connections among these problems. The MTA project has been engaged since 1996 in research and analysis, public and policy-maker education, the development of policy proposals, and the training of pre- and post-doctoral fellows.

The MTA project is based in the Belfer Center for Science and International Affairs of Harvard University's John F. Kennedy School of Government, and represents a collaboration of the Center's programs on Science, Technology, and Public Policy; International Security; and Environment and Natural Resources.

The core members of the staff of the MTA project are:

- Matthew Bunn, Co-Principal Investigator; Associate Professor of Public Policy
- John P. Holdren, Co-Principal Investigator; Director, Science, Technology, and Public Policy Program
- Henry Lee, Co-Principal Investigator; Director, Environment and Natural Resources Program
- Steven E. Miller, Co-Principal Investigator; Director, International Security Program
- Martin B. Malin, Executive Director
- Hui Zhang, Research Associate
- Andrew Newman, Research Associate
- Neal Doyle, Program Coordinator

In addition to these core staff members, the MTA project hosts research fellows and student associates from around the world engaged in research on critical issues affecting the future of nuclear energy, weapons, and nonproliferation.

Current research priorities include 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.

The MTA project provides its findings and recommendations to policy makers and to the news media through publications, briefings, workshops, and other events. MTA's current work is made possible by generous support from the John D. and Catherine T. MacArthur Foundation, the Nuclear Threat Initiative, the Ford Foundation, and the Ploughshares Fund. For more information, including full-text versions of our publications, updates on current MTA activities, biographies of all participating researchers, and other features, visit our web site, at http://www.managingtheatom.org.