

PROJECT ON MANAGING THE ATOM

ADVANCING NUCLEAR SECURITY: EVALUATING PROGRESS AND SETTING NEW GOALS

BY MATTHEW BUNN, MARTIN B. MALIN,
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HARVARD Kennedy School

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Cover Photo: A cable tie holds together a section of the outer perimeter fencing of the Y-12 National Security Complex in Oak Ridge, Tenn., on Wednesday, Dec. 19, 2012, five months after the intrusion by an 82 year-old nun and two other protesters in July 2012. Credit: AP Photo/The Knoxville News Sentinel, Saul Young.

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Executive Summary

The threat of nuclear and radiological terrorism has not disappeared, though the world has made important progress in reducing these risks. Urgent new steps are needed to build effective and lasting nuclear security worldwide. The nuclear security effort must now shift from short-term improvements toward a focus on a continued search for excellence, lasting as long as terrorist groups bent on mass destruction and the nuclear and radiological materials they might use both continue to exist.

The Continuing Threat of Nuclear and Radiological Terrorism

Nuclear and radiological terrorism remain real and dangerous threats:

- Terrorist groups continue to seek nuclear weapons and the materials and expertise needed to make them.
- Some potential nuclear weapons materials remain dangerously vulnerable, protected by security systems that would not provide an effective defense against the full spectrum of plausible adversary tactics and capabilities. All countries with nuclear weapons, separated plutonium, or highly enriched uranium (HEU) on their soil have more to do to ensure these items are effectively and lastingly secured.
- Terrorists have plotted attacks on nuclear reactors, and the nuclear Fukushima disaster highlighted the terror and disruption a successful act of sabotage could cause.
- Terrorists have also plotted attacks with radiological “dirty bombs” – which would be far simpler to execute than use of a nuclear bomb (though far less devastating).
- Al Qaeda in particular pursued a significant effort to get nuclear weapons, repeatedly attempting to buy stolen nuclear bomb material and to recruit nuclear expertise – an effort that went as far as carrying out crude tests of conventional explosives for their nuclear program in the Afghan desert. Despite the death of Osama bin Laden and the substantial disruptions the core al Qaeda organization has suffered, nearly all of the people involved in al Qaeda’s nuclear effort remain at large.
- The Japanese terror cult Aum Shinrikyo actively sought nuclear weapons, and there is some evidence that North Caucasus terrorist groups have as well.
- With at least two and possibly three groups having pursued nuclear weapons in the past quarter century, they are not likely to be the last. The imperative for nuclear security will continue as long as terrorist groups bent on mass destruction and the materials needed to make nuclear weapons both exist in the world.

Substantial Progress in Nuclear Security

Countries around the world have made substantial progress in improving nuclear security during the four-year effort to secure nuclear material that President Obama launched in 2009 – which was endorsed unanimously in UN Security Council Resolution 1887 and at the first nuclear security summit in 2010. In that sense, the effort was a major success:

- Thirteen countries eliminated all the highly enriched uranium (HEU) or separated plutonium on their soil during the four-year effort.
- Many countries strengthened their rules and procedures for securing nuclear weapons, nuclear materials, nuclear facilities, or dangerous radiological sources.
- All of the locations in non-nuclear-weapon states where enough high-quality HEU for the simplest type of terrorist nuclear bomb existed at a single site were either eliminated or had significant security improvements put in place.
- States, the International Atomic Energy Agency (IAEA), and the World Institute for Nuclear Security (WINS) are working together to strengthen nuclear security culture by publishing guides and hosting workshops.
- Programs to identify and exchange nuclear security best practices and nuclear security training programs expanded greatly.
- The nuclear security effort was elevated to the level of presidents and prime ministers, transforming the global nuclear security dialogue.
- Many additional states joined relevant nuclear security conventions and initiatives.
- The nuclear security role of the IAEA was significantly strengthened, as were the IAEA's recommendations on physical protection of nuclear materials and facilities.

But Significant Gaps Remain

Despite these successes, the four-year effort did not meet its stated goal—providing effective security for all the world's vulnerable nuclear materials. Serious dangers of nuclear theft and terrorism remain:

- Events such as the intrusion at the Y-12 facility in the United States—in which an 82-year-old nun and two other protesters penetrated multiple fences and reached a building housing thousands of bombs' worth of HEU before being stopped—make clear that, even in countries that invest heavily in nuclear security, complacency can sap performance. Building strong nuclear security cultures, in which all staff take security seriously and constantly look for ways to improve it, remains a profound challenge.
- Many countries still have important weaknesses in their approaches to nuclear security. There are still countries with: no on-site armed guards to protect nuclear facilities, even ones with plutonium or HEU; no required background checks before granting access to nuclear facilities and materials; and limited protections against insider theft. Few countries conduct realistic tests of their nuclear security systems' ability to defeat determined and creative adversaries; and few have targeted programs to assess and strengthen security culture in each relevant nuclear organization.
- The international nuclear security framework remains weak and uneven. There are no global rules that say how secure a nuclear weapon or the materials needed to make one should be. There are no agreed approaches for building confidence that states are fulfilling

their nuclear security responsibilities. After the Nuclear security summits end, it is not yet clear what forums will enable focused high-level dialogue on improving nuclear security to continue.

- Despite major improvements in nuclear security in Pakistan, it remains the locus of the world's most deadly terrorist capabilities and fastest-growing nuclear stockpile, posing significant ongoing dangers.
- India is also expanding its nuclear stockpiles, and faces significant terrorist threats – though smaller than those in Pakistan. India has so far declined most nuclear security cooperation with the United States, though some initial work is beginning. Delhi has revealed very little about how it secures its nuclear materials and facilities.
- Russia has dramatically improved nuclear security and accounting in the last two decades (with substantial US help). But Russia continues to have the world's largest nuclear stockpiles stored in the world's largest number of buildings and bunkers, and sophisticated adversaries could exploit remaining security weaknesses—especially vulnerability to insider theft. Underfunding raises serious questions about whether effective nuclear security and accounting systems will be sustained. Continued US-Russian nuclear security cooperation is needed, but the crisis in Ukraine is likely to make such cooperation more difficult.
- Over 120 research and isotope production reactors around the world still use HEU for fuel or targets. Many of these have very modest security measures. The goal of eliminating the civil use of HEU is still a long way from achievement.

Recommendations: Urgent Actions to Strengthen Nuclear Security

At the 2014 Nuclear Security Summit in The Hague and beyond, leaders around the world must commit to taking the steps necessary to close the remaining gaps in nuclear security. The effort must shift from a short-term rush for improvements, to a continuing push toward excellent nuclear security performance that lasts as long as nuclear weapons and the materials needed to make them continue to exist. All of the needed steps should be taken with an eye on sustainability over the long haul. And to be effective and sustainable, they all should be done with partnership-based approaches that respect the interests of all participants. Action is needed in several areas, described below.

Combating Complacency

Complacency is the enemy of action. Policymakers, nuclear managers, and nuclear staff around the world will only take the steps required to achieve effective nuclear security if they are convinced that nuclear terrorism is a real and urgent threat to their countries, worthy of a significant investment of time and money, and that improvements on their part are necessary to reduce the risk. To build that sense of urgency, the United States and other interested countries and organizations should:

- **Develop shared analyses of incidents and lessons learned**, including unclassified information on actual security incidents (both at nuclear sites and at non-nuclear guarded facilities) so organizations can better understand both the threat and security mistakes to be avoided.

- **Prepare threat reports and briefings** outlining the very real possibility that terrorists could get nuclear material and make a nuclear bomb, and update information on efforts to do so that some groups have made.
- **Undertake discussions of the nuclear terrorism threat among intelligence agencies;** these organizations are often a government’s main source for assessments of national security threats.
- **Conduct nuclear terrorism exercises** with policymakers from key states, which can reach officials in a way that briefings and policy memos cannot and improve preparations against attacks.
- **Launch an “Armageddon Test,”** in which intelligence agents would attempt to penetrate nuclear smuggling networks and get information leading to the recovery of weapons-usable nuclear material.

Improving Protection for Facilities and Transports

To ensure that nuclear facilities and transports are effectively secured, countries should:

- **Establish and sustain protection against the full spectrum of plausible threats.** All nuclear weapons and weapons-usable nuclear material everywhere should at least be protected against a baseline threat that includes a well-placed insider; a modest group of well-trained and well-armed outsiders, capable of operating as more than one team; and both an insider and the outsiders working together. Countries facing more capable adversaries should provide higher levels of protection.
- **Provide effective nuclear security regulation,** giving regulators the independence and resources they need, and demanding that they maintain the expertise and culture necessary to do their jobs effectively.
- **Strengthen protection against insider threats,** with measures designed to protect against theft and sabotage, including improved assessment and testing of these measures’ effectiveness.
- **Improve security for bulk processing facilities,** which appear to have been the source of almost all of the known thefts of plutonium and HEU, including in particular with nuclear material accounting and control measures for prompt detection of insider theft of even small amounts of material stolen over time.
- **Sustain effective nuclear security, including assigning sufficient resources,** including both money and trained personnel.
- **Carry out realistic tests of nuclear security systems’ performance** against intelligent adversaries looking to find ways to overcome them.
- **Accept independent nuclear security reviews,** to get ideas for improvement from experts outside the groups that designed and are operating the systems in question.
- **Strengthen protection against nuclear sabotage,** requiring every facility whose sabotage could cause a major catastrophe to provide effective protection against a wide range of plausible adversary tactics and capabilities.

- **Improve security for dangerous radiological sources**, including better protection for the transport of these sources, while shifting, where practicable, to the use of less dangerous alternatives.

Consolidating Stockpiles

To minimize the locations that might pose a risk of nuclear theft, countries should:

- **Undertake more consolidation**, with the goal of eliminating civilian HEU, constraining the accumulation of separated plutonium and the number of sites where it is used, and consolidating military stocks as much as possible. Such an effort should also use policy tools, including incentives to encourage the closure of unneeded HEU-fueled reactors and the elimination of unneeded fissile material.
- **Review the costs, risks, and benefits of each site** with nuclear weapons, HEU, or separated plutonium, eliminating any site where the costs and risks outweigh benefits. The United States and Russia, in particular, should each develop a national-level plan for accomplishing their military and civilian objectives with the smallest practicable number of sites with nuclear weapons or weapons-usable material.

Strengthening Security Culture, Best Practices, and Training

To build organizations capable of and committed to continuous improvement in nuclear security, countries should:

- **Require targeted security culture assessment and improvement programs**, in which each operator with nuclear weapons, HEU, separated plutonium, or major nuclear facilities undertakes specific efforts to assess their organization's security culture and to strengthen it over time.
- **Establish incentives for nuclear security performance** to motivate both organizations as a whole and their key staff to take security seriously and invest time and effort in finding and fixing vulnerabilities and suggesting improvements.
- **Participate in and support best practice exchanges**, and seek to ensure that all operators handling nuclear weapons, separated plutonium, HEU, or major nuclear facilities are participating as well—including participation in and financial support for best practice organizations such as WINS.
- **Provide and require high-quality training and professional certification**, so that all staff playing key roles in nuclear security meet recognized standards of competence.

Strengthening the Multi-Layered Defense Against Nuclear Terrorism

While security measures to prevent nuclear theft or sabotage are the most important steps to reduce the risk of nuclear terrorism, a multi-layered defense is also needed. States should expand intelligence and police cooperation targeted on nuclear terrorism and nuclear smuggling, put appropriate radiation detectors in place to help detect and deter nuclear smuggling, strengthen their emergency response capabilities, and take other steps to thwart a successful attack if nuclear material is ever stolen.

Building a More Effective Global Nuclear Security Framework

The world needs a stronger global nuclear security framework, a structure that helps states cooperate to: establish standards and goals for nuclear security; discuss and decide on next steps to improve nuclear security; confirm that states are fulfilling their responsibility to provide effective security; and track states' progress in fulfilling their nuclear security commitments. To strengthen this framework, states should:

- **Commit, along with like-minded states, to protecting nuclear stockpiles against the full spectrum of plausible adversaries**, including, at a minimum, the “baseline” threat described earlier in “Improving Protection for Facilities and Transports.”
- **Undertake sustained, partnership-based nuclear security cooperation**, without letting political disputes interfere with cooperation that serves the interests of all sides. The current crisis in Ukraine should not be permitted to stop US-Russian cooperation on programs that serve each country's national interest.
- **Ratify and implement existing treaties**, join cooperative initiatives such as the Global Initiative to Combat Nuclear Terrorism (GICNT) and the Global Partnership Against the Spread of Weapons and Materials of Mass Destruction, and commit to implementing the treaties provisionally pending ratification.
- **Act to strengthen the IAEA's nuclear security role**, providing it with additional political support, direction, and resources.
- **Take steps to build global confidence that nuclear security systems are effective**, including by publishing detailed information on their nuclear security practices (while protecting information that would be helpful to terrorists) and requesting international reviews led by the IAEA. States with military stocks should work out measures to build confidence in the security of military stocks without revealing information that must remain secret.
- **Continue the dialogue beyond the nuclear security summits**, through multiple forums ranging from IAEA meetings to those of cooperative initiatives such as GICNT to bilateral engagements.

These steps will not be easy. Complacency, secrecy, sovereignty, politics, costs, and bureaucracy will all pose formidable obstacles. But the very real successes achieved to date make clear that these obstacles can be overcome. States around the world need to take action to build a global system that will provide effective nuclear security for as long as nuclear weapons and the materials needed to make them continue to exist.

I. Beyond the Four-Year Effort: The Continuing Challenge of Nuclear Security

The four-year effort to secure the world's vulnerable nuclear material that President Obama launched in April 2009 is now over. As this report will describe, in one sense the effort was a major success: it elevated discussions of nuclear security from technical specialists to presidents and prime ministers, cut through red tape, and drove improvements in security for nuclear weapons and materials in many countries. Thirteen countries eliminated all the highly enriched uranium (HEU) or separated plutonium on their soil during the four-year effort. The global dialogue about nuclear security has been transformed.

But the four-year effort did not succeed in meeting its stated goal—providing effective security for all the world's vulnerable nuclear materials. Serious dangers of nuclear theft and terrorism remain. Incidents such as the 2012 intrusion at the Y-12 nuclear facility in the United States—where hundreds of tons of HEU are stored—make clear that, even in countries that have invested heavily in nuclear security for decades, complacency can creep in and sap security.

Indeed, nuclear security is not a switch to be flipped, permanently taking nuclear material from “vulnerable” to “secure,” but rather an ongoing struggle to combat complacency, find and fix vulnerabilities, improve practices, and adapt to ever-changing threats and circumstances. The leaders gathering for the nuclear security summit in The Hague in 2014 must avoid the temptation to conclude that the job is done. There will still be work to do to improve nuclear security for as long as terrorists bent on mass destruction and the materials needed to make nuclear weapons both exist. Instead, the leaders who will gather in The Hague in March 2014 must work to transform the nuclear security effort into an ongoing, long-term search for excellence—because organizations that are satisfied with their nuclear security and not striving to do better are in most cases going to get worse.

The four-year effort itself focused on security for nuclear weapons and the materials needed to make them, but the nuclear security dialogue has broadened to encompass security of major nuclear facilities that might be sabotaged; security of radiological sources that might be dispersed in a so-called “dirty bomb;” interdicting nuclear and radiological smuggling and identifying the sources of seized materials; and responding to nuclear and radiological emergencies. The leaders gathered in The Hague will need to find a structure that supports progress in these areas as well.

Nuclear security is ultimately a national responsibility—but all countries have an interest in making sure that other countries are fulfilling that responsibility appropriately. Because nuclear material can readily be transported across borders, insecure nuclear material anywhere is a threat to everyone, everywhere. Ultimately, international cooperation is an essential part of addressing the threat. States should do everything they can to avoid letting crises and political disputes—from the current crisis over Ukraine's future to disagreements over disarmament or democracy—interfere with cooperation that serves the security interests of all.

Achieving the steps just outlined will require expanded international cooperation and a strengthened global framework for governing nuclear security. Countries will have to find approaches to carry forward the dialogue after the fourth and probably last nuclear security summit slated for

Washington, D.C., in 2016. Before then, the leaders at The Hague will need to take the next steps to strengthen the international nuclear security framework, to make it possible for countries to come together and set and meet clear nuclear security objectives.

Efforts to sustain effective nuclear security face a fundamental obstacle: complacency. Unless political leaders and nuclear security managers are convinced that the threat is real, that it affects their country directly, and that action in their own country and not just in some foreign land is needed to reduce the risk, they will not take the actions required to reduce the danger of nuclear and radiological terrorism. Even once the fundamental obstacle of complacency has been surmounted, these efforts will continue to have to overcome bureaucratic impediments, strictures imposed by secrecy, political disputes, organizational weaknesses, and resource constraints—among other obstacles. However, officials motivated by a clear perception of the threat and the steps needed to address it can overcome these obstacles.

This report offers an assessment of the four-year effort and what remains to be done. It focuses primarily on nuclear weapons and the materials needed to make them, but also includes brief discussions of security for nuclear facilities, for radiological sources, and of the broader chain of steps needed to combat nuclear and radiological terrorism. The report begins by offering a brief summary of the continuing threat of nuclear theft and terrorism. It then outlines a set of goals for security for nuclear weapons and materials. The largest chapter offers an assessment of progress toward these goals in four categories: (1) standards of security for the facilities and transporters handling nuclear weapons and materials; (2) consolidating these stocks in fewer locations; (3) security culture, the use of best practices, and training; (4) and global governance of nuclear security. Finally, it outlines a set of recommendations for strengthening the global nuclear security effort for the long haul. The report also includes brief descriptions of security breaches and draws lessons from those incidents about what threats against which nuclear security systems states must be prepared to defend.

Incident: Intrusion at Y-12, United States, 2012

In the early morning hours of July 28, 2012, an 82 year-old nun and two other protesters broke into the Y-12 nuclear weapons production facility—sometimes referred to as the Fort Knox of HEU—in Oak Ridge, Tennessee. Equipped with hammers, paint, blood, and a pair of bolt cutters, they cut through four fences—three of them with intrusion detectors—setting off alarms, and traversed a 600-meter semi-wooded area until they arrived at the wall of a building housing hundreds of tons of HEU, enough for thousands of nuclear weapons. They painted blood on the walls, sang songs, and pounded on the building with their hammers, before finally being accosted by a single guard. Fortunately, they were not terrorists armed with explosives and did not mean any harm (and the building has specially designed walls that would be very difficult for terrorists to penetrate, along with extensive interior protections). But later investigations revealed a security culture failure of epic proportions, not only in the intrusion but also in the response.

How could this happen? The subsequent investigation of the incident by the Department of Energy (DOE) Inspector General revealed “multiple system failures on several levels” and “troubling displays of ineptitude” in Y-12’s security practices. For example, it turned out the site had a new intrusion detection system, which was setting off ten times as many false alarms as usual. Normally, the guard at the central alarm station could check if an alarm was caused by a real intruder using cameras along the fence—but the cameras had been broken for months. They had not been put on the priority list to be fixed, on the assumption that guards could always check out the alarms; but it appears that with so many false alarms, the guards had grown weary of investigating. For whatever reason, even a series of alarms on a path leading directly to the HEU building was not enough to prompt the guard at the central alarm station to take more serious action. The heavily armed guards inside the facility heard the hammering and thought it might be construction they had not been told about, even though it was before dawn, and did not bother to check.¹

In short, there was a profound breakdown in security culture—among those who tolerated an intrusion system setting off ten times as many false alarms as usual, among those who did not bother to fix the cameras, among the guards who did not react to the alarms or the hammering, and eventually in the armed response to the intrusion.

Perhaps even more troubling, prior to the intrusion, officials at DOE headquarters thought of Y-12 as one of their most secure sites, and had no idea such a serious erosion of security practices had occurred. Tom D’Agostino, then-administrator of the National Nuclear Security Administration (NNSA), warned that “this incident raises important questions about the security of Category I materials [those requiring the highest level of security] throughout the DOE complex.”²

Lessons:

1. People and organizations matter—a poor security culture can severely undermine security even at facilities with modern security equipment, extensive security spending, stringent security rules, and regular security testing.
2. Governments can never be complacent about nuclear security, even in countries with strong security rules and substantial nuclear security budgets.
3. Those responsible for carrying out assessments and inspections need to find ways to understand not just the equipment in place and the performance planned on paper or shown during long-scheduled tests, but what is actually going on every day.
4. Detection and assessment equipment must be fully operational and adequately maintained if it is to be effective.

¹ For a detailed account of the incident, see Office of the Inspector General US Department of Energy, *Inquiry Into the Security Breach at the National Nuclear Security Administration’s Y-12 National Security Complex*, DOE/IG-0868 (Washington, D.C., DOE, August, 2012); http://energy.gov/sites/prod/files/IG-0868_0.pdf (accessed March 8, 2014), p. 14.

² US Department of Energy, *Inquiry Into the Security Breach*, p. 14.

II. Nuclear and Radiological Terrorism: The Continuing Threat

Unfortunately, nuclear and radiological terrorism remain real and dangerous threats.¹ The conclusion the assembled leaders reached at the Washington Nuclear Security Summit and reaffirmed in Seoul remains correct: “Nuclear terrorism continues to be one of the most challenging threats to international security. Defeating this threat requires strong national measures and international cooperation given its potential global political, economic, social, and psychological consequences.”²

There are three types of nuclear or radiological terrorist attack:

- **Nuclear weapons.** Terrorists might be able to get and detonate an assembled nuclear weapon made by a state, or make a crude nuclear bomb from stolen separated plutonium or HEU. This would be the most difficult type of nuclear terrorism for terrorists to accomplish—but the devastation could be absolutely horrifying, with political and economic aftershocks reverberating around the world.
- **“Dirty bombs.”** A far simpler approach would be for terrorists to obtain radiological materials—available in hospitals, industrial sites, and more—and disperse them to contaminate an area with radioactivity, using explosives or any number of other means. In most scenarios of such attacks, few people would die from the radiation—but the attack could spread fear, force the evacuation of many blocks of a major city, and inflict billions of dollars in costs of cleanup and economic disruption. While a dirty bomb attack would be much easier for terrorists to carry out than an attack using a nuclear explosive, the consequences would be far less—an expensive and disruptive mess, but not the heart of a major city going up in smoke.
- **Nuclear sabotage.** Terrorists could potentially cause a Fukushima-like meltdown at a nuclear reactor or sabotage a spent fuel pool or high-level waste store. An unsuccessful sabotage would have little effect, but a successful one could spread radioactive material over a huge area. Both the scale of the consequences and the difficulty of carrying out a successful attack would be intermediate between nuclear weapons and dirty bombs.

Overall, while actual terrorist use of a nuclear weapon may be the least likely of these dangers, its consequences would be so overwhelming that we believe it poses the most significant risk. A similar judgment drove the decision to focus the four-year effort on securing nuclear weapons

¹ For an up-to-date assessment, see William H. Tobey and Pavel Zolotarev, “The Nuclear Terrorism Threat” (Pataya, Thailand: Presentation, Meeting of the 2014 Nuclear security summit Sherpas, Hosted by the Thai Ministry of Foreign Affairs, January 13, 2014), http://belfercenter.ksg.harvard.edu/publication/23879/nuclear_terrorism_threat.html?breadcrumb=%2Fexperts%2F1969%2Fwilliam_h_tobey (accessed March 8, 2014). For an earlier joint US-Russian account, see Matthew Bunn et al., *The U.S.-Russia Joint Threat Assessment of Nuclear Terrorism* (Cambridge, Mass.: Belfer Center for Science and International Affairs, Harvard Kennedy School, and Institute for US and Canadian Studies, June, 2011), <http://belfercenter.ksg.harvard.edu/publication/21087/> (accessed March 11, 2014); Matthew Bunn, *Securing the Bomb 2010: Securing all Nuclear Materials in Four Years* (Cambridge, Mass.: Project on Managing the Atom, Harvard University, and Nuclear Threat Initiative 2010), <http://www.nti.org/securingthebomb> (accessed March 11, 2014), pp. 1–22.

² “Seoul Communique,” 2012 Nuclear Security Summit (Seoul, Korea, March 27, 2012), https://www.nss2014.com/sites/default/files/documents/seoul_communique_final.pdf (accessed March 8, 2014).

and the materials needed to make them. Most of this report will focus on the threat of terrorist use of nuclear explosives, but the overall global governance framework for nuclear security is relevant to all of these dangers.

The danger of nuclear terrorism is driven by three key factors—terrorist intent to escalate to the nuclear level of violence; potential terrorist capability to do so; and the vulnerability of nuclear weapons and the materials needed to enable terrorists to carry out such an attack—the motive, means, and opportunity of a monstrous crime.

Terrorist intent. While most terrorist groups are still focused on small-scale violence for local political purposes, we now live in an age that includes some groups intent on inflicting large-scale destruction to achieve their objectives. Over the past quarter century, both al Qaeda and the Japanese terror cult Aum Shinrikyo seriously sought nuclear weapons and the nuclear materials and expertise needed to make them. Al Qaeda had a focused program reporting directly to Ayman al-Zawahiri (now head of the group), which progressed as far as carrying out crude but sensible conventional explosive tests for the nuclear program in the desert of Afghanistan. There is some evidence that North Caucasus terrorists also sought nuclear weapons—including incidents in which terrorist teams were caught carrying out reconnaissance on Russian nuclear weapon storage sites, whose locations are secret.³

Despite the death of Osama bin Laden and the severe disruption of the core of al Qaeda, there are no grounds for complacency. There is every reason to believe Zawahiri remains eager to inflict destruction on a nuclear scale. Indeed, despite the large number of al Qaeda leaders who have been killed or captured, nearly all of the key players in al Qaeda’s nuclear program remain alive and at large—including Abdel Aziz al-Masri, an Egyptian explosives expert who was al Qaeda’s “nuclear CEO.” In 2003, when al Qaeda operatives were negotiating to buy three of what they thought were nuclear weapons, senior al Qaeda officials told them to go ahead and make the purchase if a Pakistani expert with equipment confirmed the items were genuine. The US government has never managed to determine who the Pakistani nuclear weapons expert was in whom al Qaeda had such confidence—and what he may have been doing in the intervening decade.

More fundamentally, with at least two, and probably three, groups having gone down this path in the past 25 years, there is no reason to expect they will be the last. The danger of nuclear terrorism will remain as long as nuclear weapons, the materials needed to make them, and terrorist groups bent on large-scale destruction co-exist.

Potential terrorist capabilities. No one knows what capabilities a secret cell of al Qaeda may have managed to retain or build. Unfortunately, it does not take a Manhattan Project to make a nuclear bomb—indeed, over 90 percent of the Manhattan Project effort was focused on making the nuclear materials, not on designing and building the weapons. Numerous studies by the United States and other governments have concluded that it is plausible that a sophisticated terrorist group could make a crude nuclear bomb if it got enough separated plutonium or HEU.⁴ A “gun-type” bomb, such as the weapon that obliterated Hiroshima, fundamentally involves slamming two pieces of HEU together at high speed. An “implosion-type” bomb, which is needed to get a sub-

³ Bunn et al., *US-Russia Joint Threat Assessment*.

⁴ Matthew Bunn and Anthony Wier, “Terrorist Nuclear Weapon Construction: How Difficult?,” *Annals of the American Academy of Political and Social Science*, Vol. 607 (September 2006), pp. 133–149.

stantial explosive yield from plutonium, requires crushing nuclear material to a higher density—a more complex task, but still plausible for terrorists, especially if they got knowledgeable help.

Many analysts argue that, since states spend billions of dollars and assign hundreds or thousands of people to building nuclear weapons, it is totally implausible that terrorists could carry out this task. Unfortunately, this argument is wrong, for two reasons. First, as the Manhattan Project statistic suggests, the difficult part of making a nuclear bomb is making the nuclear material. That is what states spend billions seeking to accomplish. Terrorists are highly unlikely to ever be able to make their own bomb material—but if they could get stolen material, that step would be bypassed. Second, it is far easier to make a crude, unsafe, unreliable bomb of uncertain yield, which might be delivered in the back of a truck, than to make the kind of nuclear weapon a state would want in its arsenal—a safe, reliable weapon of known yield that can be delivered by missile or combat aircraft. It is highly unlikely terrorists will ever be able to build that kind of nuclear weapon.

Remaining vulnerabilities. While many countries have done a great deal to strengthen nuclear security, serious vulnerabilities remain. Around the world, there are stocks of nuclear weapons or materials whose security systems are not sufficient to protect against the full range of plausible outsider and insider threats they may face. As incidents like the intrusion at Y-12 in the United States in 2012 make clear, many nuclear facilities and transporters still grapple with serious problems of security culture. It is fair to say that every country where nuclear weapons, weapons-usable nuclear materials, major nuclear facilities, or dangerous radiological sources exist has more to do to ensure that these items are sustainably secured and accounted for.

At least three lines of evidence confirm that important nuclear security weaknesses continue to exist. First, seizures of stolen HEU and separated plutonium continue to occur, including, mostly recently HEU seizures in 2003, 2006, 2010, and 2011.⁵ These seizures may result from material stolen long ago, but, at a minimum, they make clear that stocks of HEU and plutonium remain outside of regulatory control. Second, in cases where countries do realistic tests to probe whether security systems can protect against teams of clever adversaries determined to find a weak point, the adversaries sometimes succeed—even when their capabilities are within the set of threats the security system is designed to protect against. This happens with some regularity in the United States (though less often than before the 9/11 attacks); if more countries carried out comparable performance tests, one would likely see similar results. Third, in real non-nuclear thefts and terrorist attacks around the world, adversaries sometimes demonstrate capabilities and tactics well beyond what many nuclear security systems would likely be able to handle (see the discussion of the recent Västberga incident in Sweden).

⁵ Additionally, in recent years there have been several seizures of scrap metal contaminated with surprisingly large amounts of HEU; it appears that one or more HEU-processing facilities in the former Soviet Union has been or is being dismantled without sufficient care for the resulting scrap. Interview with US laboratory nuclear smuggling expert, July 2013. See also “Illicit Trafficking in Weapons-Useable Nuclear Material: Still More Questions Than Answers,” Center for Nonproliferation Studies, December 11, 2011, <http://www.nti.org/analysis/articles/illicit-trafficking-weapons-useable-nuclear-material-still-more-questions-answers/> (accessed March 8, 2014). US Congress, Senate, Committee on Foreign Relations, *Enhancing Non-Proliferation Partnerships in the Black Sea Region: A Minority Staff Report* (Washington, D.C.: US Government Printing Office, 2011), <http://wid.ap.org/documents/np-minority-report.pdf>. Nick Amies, “US Concerns Over Nuclear Smuggling Between Europe, North Africa,” *Deutsche Welle*, May 10, 2011, <http://www.dw.de/dw/article/0,,15434811,00.html> (accessed March 11, 2014). Desmond Butler, “Officials Say Crime Ring has Uranium,” AP foreign, September 27 2011, <http://www.theguardian.com/world/feedarticle/9866962> (accessed March 8, 2014).

Incident: Cash Depot Robbery in Västberga, Sweden, 2009

In September 2009, a group of masked men armed with automatic weapons and explosives used a stolen helicopter to rob a cash depot in Västberga, Sweden. Early in the morning, the helicopter hovered above the depot, which was owned by one of the world's largest security companies, as the men landed on the roof and used a sledgehammer to break through a skylight. The thieves, some of whom were later identified as former members of a Serbian paramilitary group, had automatic weapons and used explosives to blast their way to the money in the building. The entire raid took approximately twenty minutes and the thieves avoided injuring the nearly two dozen people in the facility at the time. The masked men hoisted millions of dollars up to the helicopter and escaped without being pursued because they anticipated the police response.

Prior to the robbery, they left a bag with the word “bomb” written on it at the police heliport to prevent any helicopter pursuit and placed caltrops (spikes) on the road near the depot to prevent a car chase. About 15 miles from the depot, they transferred to ground vehicles which had not been at the scene of the crime and abandoned the helicopter.

Many of the thieves were later caught and convicted, but most of the money was never recovered—and the security systems in place clearly were insufficient to protect against the threat.

This incident offers two lessons:

1. Adversaries can employ a broad range of capabilities, including military-style tactics and weaponry; use of helicopters to rapidly surmount barriers and fly away; and means to delay the arrival of response forces.
2. Even countries that believe they face low domestic threats have to worry about adversaries arriving from elsewhere; in this case, many of the robbers came from the other side of the continent.

Of course, the initial theft of nuclear material would be only the first step. Adversaries would have to smuggle the material to wherever they wanted to make their bomb, and ultimately to the target. A variety of measures have been put in place in recent years to try to stop nuclear smuggling, from radiation detectors to national teams trained and equipped to deal with nuclear smuggling cases—and more should certainly be done. But once nuclear material has left the facility where it is supposed to be, it could be anywhere, and finding and recovering it poses an enormous challenge. The immense length of national borders, the huge scale of legitimate traffic, the myriad potential pathways across these borders, and the small size and weak radiation signal of the materials needed to make a nuclear bomb make nuclear smuggling extraordinarily difficult to stop.

There is also the danger that a state such as North Korea might consciously decide to provide nuclear weapons or the materials needed to make them to terrorists. This possibility cannot be ruled out, but there is strong reason to believe that such conscious state decisions to provide these capabilities are a small part of the overall risk of nuclear terrorism. Dictators determined to maintain their power are highly unlikely to hand over the greatest weapon they have to terrorist groups they cannot control, who might well use it in ways that would provoke retaliation that would remove the dictator from power forever. Although nuclear forensics is by no means perfect, it would be only one of many lines of evidence that could potentially point back to the state that provided the materials; no state could ever be confident they could make such a transfer without

being caught.⁶ And terrorists are unlikely to have enough money to make a substantial difference in either the odds of regime survival or the wealth of a regime's elites, even in North Korea, one of the poorest countries on earth. On the other hand, serious risks would arise in North Korea, or other nuclear-armed states, in the event of state collapse—and as North Korea's stockpile grows, one could imagine a general managing some of that stockpile concluding he could sell a piece of it and provide a golden parachute for himself and his family without getting caught.

No one knows the real likelihood of nuclear terrorism. But the consequences of a terrorist nuclear blast would be so catastrophic that even a small chance is enough to justify urgent action to reduce the risk. The heart of a major city could be reduced to a smoldering radioactive ruin, leaving tens to hundreds of thousands of people dead. The perpetrators or others might claim to have more weapons already hidden in other major cities and threaten to set them off if their demands were not met—potentially provoking uncontrolled evacuation of many urban centers. Devastating economic consequences would reverberate worldwide. Kofi Annan, while serving as Secretary-General of the United Nations, warned that the global economic effects of a nuclear terrorist attack in a major city would push “tens of millions of people into dire poverty,” creating a “second death toll throughout the developing world.”⁷

Making plutonium or HEU is well beyond the plausible capabilities of terrorist groups. Hence, if all the world's stockpiles of these materials can be secured from falling into terrorist hands, nuclear terrorism can be prevented. Improved nuclear security is the single point on the terrorist pathway to the bomb where government policies can do the most to reduce the danger. After a nuclear weapon or the material needed to make one has been stolen, every later step on the terrorist pathway is easier for terrorists to take and harder for governments to block.

⁶ Keir A. Lieber and Daryl G. Press, “Why States Won't Give Nuclear Weapons to Terrorists,” *International Security* Vol. 31, No. 8 pp. 80-104 (Summer 2013), DOI: 10.1162/ISEC_a_00127.

⁷ Kofi Annan, “A Global Strategy for Fighting Terrorism: Keynote Address to the Closing Plenary,” *The International Summit on Democracy, Terrorism and Security* (Madrid: Club de Madrid, 2005), <http://english.safe-democracy.org/keynotes/a-global-strategy-for-fighting-terrorism.html> (accessed March 10, 2014).

III. Nuclear Security: What Goals Are Necessary?

The stated goal of the four-year effort was to secure all vulnerable nuclear material worldwide. But neither the Obama administration nor any other government or international organization ever defined what success of this effort would look like—how much improvement in security for what stocks of nuclear weapons or weapons-usable materials would be sufficient.⁸ Instead, the Obama administration saw the four-year effort as a “forcing function” to help “accelerate ongoing US nonproliferation programs, drive closer integration of nuclear nonproliferation programs across the federal government, and mobilize greater international responsibility for and commitment to nuclear material security.”⁹ In one account, the administration identified the goal as merely making “significant progress” toward securing the world’s most vulnerable materials, a stark contrast from the goal of securing “all” such materials in the original speech.¹⁰ Particular programs outlined what they sought to accomplish during the four-year effort, but these program goals were quite partial, and did not by any means provide for effective security for all of the world’s vulnerable weapons-usable nuclear material.¹¹

In the absence of an official definition of the goal, our last report recommended a set of goals, focused on sustainably reducing to a low level the overall risk that a nuclear weapon or enough weapons-usable nuclear material to make one could be stolen.¹²

Facilities or transports with nuclear weapons or weapons-useable materials must be reliably protected against the full suite of plausible adversary capabilities (both insider and outsider) that they might face. Hence, how much security is enough will vary from country to country, depending on what kinds of capabilities terrorists or criminals can muster. A security system that was perfectly adequate in Canada might still be considered “vulnerable” or “high risk” in Pakistan.

⁸ US Congress, Government Accountability Office, *Further Actions Needed by U.S. Agencies to Secure Vulnerable Nuclear and Radiological Materials*, GAO-12-512T (Washington, D.C.: GAO, 2012), <http://www.gao.gov/assets/590/589345.pdf> (accessed March 8, 2014), p. 6.

⁹ GAO, *Further Actions Needed*, p. 7.

¹⁰ See “Make Significant Progress Toward Securing the Most Vulnerable Materials Worldwide Within Four Years” (Washington, D.C.: Performance.gov, no date), http://goals.performance.gov/goal_detail/doe/423/print#overview (accessed March 8, 2014).

¹¹ In particular, the Global Threat Reduction Initiative (GTRI), a program of the National Nuclear Security Administration (NNSA) at the US Department of Energy (DOE) set a goal of completing the removal or confirming the disposal of 4,353 kilograms of potentially vulnerable highly enriched uranium (HEU) or plutonium by December 2013, which DOE defined as the end of the four-year effort. NNSA’s International Material Protection and Cooperation program set a goal of completing security upgrades on all of the 229 buildings with plutonium or HEU where it has been cooperating with Russia. See “Make Significant Progress,” http://goals.performance.gov/goal_detail/doe/423/print#overview (accessed March 8, 2014). As discussed later in this report, by NNSA’s accounting GTRI’s goal was exceeded (though it did not succeed in removing much of the material it had originally planned to remove), while the goal for installing upgrades in Russia was not met, because of delays in Russian approval of contracts.

¹² Matthew Bunn, Eben Harrell, and Martin B. Malin, *Progress on Securing Nuclear Weapons and Materials: The Four-Year Effort and Beyond* (Cambridge, Mass.: Project on Managing the Atom, Harvard University, March, 2012), http://belfercenter.ksg.harvard.edu/files/Progress_In_The_Four_Year_Effort_web.pdf. (accessed March 7, 2014), pp. 3-5.

Securing Nuclear Weapons and Materials: A Definition of Success

- All nuclear weapons and stocks of HEU and plutonium are protected against at least a baseline threat—and have additional protection in locations that are threatened by more capable adversaries.
- All nuclear weapons and weapons-usable nuclear materials have been consolidated in as few locations as possible, and civilian use of HEU has been phased out.
- All countries where nuclear weapons or weapons-usable nuclear materials exist have established and enforced effective nuclear security rules, and ensured that all operators responsible for these stocks have the financial and personnel resources to implement and sustain effective security and accounting.
- A structure of governance is in place that provides mechanisms for setting agreed standards, reviewing performance, building confidence that states are implementing nuclear security effectively, and identifying priorities for next steps.
- All operators handling nuclear weapons and weapons-usable nuclear materials have implemented best practices in nuclear security and established strong security cultures focused on continually improving security in the face of an evolving threat.

However, in a world with terrorists with global reach, countries need to require facilities and transporters working with nuclear weapons, HEU, and separated plutonium, to protect against at least:

- a modest group of well-armed and well-trained outsiders;
- a well-placed insider;
- both outsiders and an insider working together, using a broad range of possible tactics.

Countries facing more capable adversaries should provide even higher levels of protection.

IV. Assessing Progress and Remaining Gaps

Nuclear security around the world has improved substantially during the four-year effort and in the years leading up to it. Yet, there is more to be done to secure nuclear weapons and the materials needed to make them; nuclear facilities that might be sabotaged; and radiological sources.

A multi-pronged approach is needed that includes security measures where these items exist; measures to stop nuclear and radiological smuggling; emergency response; efforts to counter the terrorist groups interested in nuclear and radiological attacks; steps to prevent and deter state assistance with nuclear or radiological terrorism; and more.¹³ But security and accounting measures to prevent terrorists and thieves from getting nuclear weapons and materials are the most important single chokepoint blocking the terrorist pathway to the bomb.

The goal, as just discussed, must be to reduce the overall risk of nuclear theft and terrorism to the lowest practicable level. But balancing the risk-reduction benefits of increased security against the costs and inconveniences that come with it is a difficult task—particularly as there are no clear measures of the total remaining risk, which facilities are the riskiest, or how much risk reduction would come from any particular investment.

Measuring progress toward a uniformly low risk of nuclear theft is a difficult task. Both nuclear security system performance and terrorist or criminal capabilities change over time, largely in secret. Hence, no comprehensive quantitative measures of the effectiveness of nuclear security are available.¹⁴ In the absence of such measures, this report will qualitatively assess the progress made during the four-year effort and the work remaining to be done in four categories: strengthening the security measures and standards in place for nuclear facilities and transports around the world; reducing the number of sites with nuclear weapons and weapons-useable materials; boosting security culture, implementing best practices, and providing effective training; and strengthening global governance of nuclear security.

There are two principal pathways by which nuclear security improvements occur. In some cases, the US government (or, less often, another donor state or organization) works with countries to agree on a particular nuclear security improvement step and finances much of the initial work—usually with arrangements in place for the host country to take over and sustain the effort after

¹³ See “Beyond Nuclear Security,” in Matthew Bunn, *Securing the Bomb 2008* (Cambridge, Mass.: Project on Managing the Atom, Belfer Center for Science and International Affairs, Harvard Kennedy School of Government and Nuclear Threat Initiative, November 2008), pp. 70-87, http://www.nti.org/media/pdfs/Securing_The_Bomb_2008.pdf?_=1317161155 (accessed March 8, 2014). See also Michael Levi, *On Nuclear Terrorism* (Cambridge, Mass.: Harvard University Press, 2007).

¹⁴ The NTI Nuclear Security Index provides a valuable assessment of whether or not countries can be shown to have taken particular nuclear security steps, such as establishing a DBT that operators are required to protect against or ratifying relevant conventions. It also provides an assessment of the overall nuclear materials security conditions in a country by looking at openly available information on indicators in five categories relevant to the risk of theft. But it is not designed to assess what kinds of adversary capabilities the security systems within a country could protect against, or what the odds are that adversaries could put together enough capability to defeat the security system; hence, it does not provide an assessment of how the probability of nuclear theft varies from one country to the next. (One of the authors [Bunn] is member of the international panel that advised NTI on indicators to include in the index.) See Nuclear Threat Initiative and Economist Intelligence Unit, *NTI Nuclear Materials Security Index: Building a Framework for Assurance, Accountability, and Action*, 2nd Edition (Washington, D.C.: NTI, January, 2014), <http://www.ntiindex.org/> (accessed March 10, 2014).

an initial period. In other cases, states undertake security improvements on their own, financing the work themselves. Although this second pathway receives less attention in US debates, it is ultimately the better approach for US security because indigenous improvements are more likely to be sustained. US agencies track the nuclear security improvements which they finance, but data on indigenous improvements is harder to come by. The discussion below attempts to assess overall improvements in nuclear security, including both categories.

Improvements in the Protection of Nuclear Weapons and Materials

In recent years, many countries have strengthened their requirements and procedures for securing nuclear weapons and weapons-usable nuclear materials. In a recent survey with respondents from all but two of the states with nuclear weapons and most of the non-nuclear-weapon states where separated plutonium and HEU exist, all of the respondents reported that their countries had made their nuclear security requirements either “much more stringent” or “modestly more stringent” in the last 15 years.¹⁵ Overwhelmingly, the experts reported that their countries had made either dramatic or major changes in the design basis threat (DBT)—the set of adversary capabilities and tactics against which their nuclear security systems are designed to provide protection. Other improvements covered a wide spectrum, from increased use of realistic testing of the performance of security systems to greater capabilities for guard forces at nuclear sites. Some of these changes occurred during the four-year nuclear security effort, and some had already been accomplished when that effort began. The Nuclear Threat Initiative’s (NTI) Nuclear Materials Security Index for 2014 reports that during the four-year effort:

- Belgium strengthened its regulations that updated its DBT, beefed up protections against insider threats, and upgraded access control procedures.¹⁶
- Belarus put in place new rules on protecting against insider threats and securing material during transportation. Belarusian and US experts also worked together to implement major security improvements at the single site in Belarus with HEU.¹⁷
- Pakistan strengthened rules on physical protection of its civilian nuclear infrastructure (security for Pakistan’s military stocks is discussed in more detail below).¹⁸
- Canada and Germany strengthened their rules on securing nuclear material during transport.¹⁹

¹⁵ Matthew Bunn and Eben Harrell, *Threat Perceptions and Drivers of Change in Nuclear Security Around the World: Results of a Survey*, (Cambridge, Mass.: The Project on Managing the Atom, Belfer Center for Science and International Affairs, Harvard University, February 2014), pp. 7.

¹⁶ *NTI Nuclear Materials Security Index*, Belgium Country Profile, <http://ntiindex.org/countries/belgium/> (accessed March 8, 2014).

¹⁷ *NTI Nuclear Materials Security Index*, Belarus Country Profile, <http://ntiindex.org/countries/belarus/> (accessed March 8, 2014). Also data provided by NNSA officials, January 2014.

¹⁸ *NTI Nuclear Materials Security Index*, Pakistan Country Profile, <http://ntiindex.org/countries/pakistan/> (accessed March 8, 2014).

¹⁹ *NTI Nuclear Materials Security Index*, Canada and Germany Country Profiles, <http://ntiindex.org/countries/canada/>, <http://ntiindex.org/countries/germany/> (accessed March 8, 2014).

- The Netherlands toughened its rules on vetting of personnel with access to nuclear materials and facilities.²⁰
- Uzbekistan established requirements for testing the performance of nuclear security systems.²¹
- Japan took steps to strengthen protection against insider threats.²² Indeed, Japan approved a broad range of changes to its nuclear security rules in December 2011 and March 2012, including new rules on cybersecurity, on protection for backup power supplies that might be sabotaged, on searches with metal detectors and nuclear material detectors before entering protected areas, and on backup power supplies for security systems. Protection against insider threats remains an issue: there are still no background checks before people are granted access to potential nuclear bomb material in Japan.²³

In addition, after the 2007 break-in at the Pelindaba nuclear facility, South Africa completed millions of dollars' worth of security improvements, in part with US help, greatly strengthening security for the hundreds of kilograms of HEU from its former nuclear weapons program. For the first time, South Africa instituted a regulatory requirement that sites handling nuclear material be able to protect against a specified DBT.²⁴ France approved major new nuclear security regulations in 2009 and 2011, which strengthened its DBT, ensured consistency with the Amendment to the Convention on the Physical Protection of Nuclear Material, and strengthened requirements for protection against sabotage.²⁵

In Kazakhstan, a long-running Kazakh-US-Russian joint project to secure fissile material (primarily plutonium) left behind by Soviet nuclear testing was completed during the four-year effort, drastically reducing what had been a dangerous risk of nuclear theft, as metal scavengers came perilously close to the weapons-grade plutonium.²⁶ The four-year effort also saw the completion of a major Kazakh-US joint effort to beef up security for irradiated breeder reactor fuel

²⁰ *NTI Nuclear Materials Security Index*, Netherlands Country Profile, <http://ntiindex.org/countries/netherlands/> (accessed March 8, 2014).

²¹ *NTI Nuclear Materials Security Index*, Uzbekistan Country Profile, <http://ntiindex.org/countries/uzbekistan/> (accessed March 8, 2014).

²² *NTI Nuclear Materials Security Index*, Japan Country Profile, <http://ntiindex.org/countries/japan/> (accessed March 8, 2014).

²³ The new regulations and the ongoing controversy over background checks are described in Kaoru Naito, "Nuclear Security Regime in Japan: Policies and Activities of Japanese Government," *Proceedings of International Nuclear Security: Enhancing Global Efforts*, Vienna, July 1–5, 2013 (Vienna: International Atomic Energy Agency, 2013).

²⁴ Interview with South African nuclear security expert, March 2013, and discussions with NNSA officials, June 2013.

²⁵ See, for example, Gen. Laurent Demolins, "Implementing a New Legal and Regulatory Framework to Enhance Protection of Nuclear Material and Facilities," presentation to US Nuclear Regulatory Commission's "International Regulators Conference on Nuclear Security," December 4–5 2012, Rockville, Maryland, <http://www.nrcsecurityconference.org/slides/Dec4/France.pdf> (accessed March 8, 2014) and Patrick Raymond, presentation to the Institute for Nuclear Material Management, "Risk Informing Security Workshop," Stone Mountain, Georgia, February 11–12, 2014.

²⁶ See Eben Harrell and David E. Hoffman, *Plutonium Mountain: Inside the 17-Year Mission to Secure a Legacy of Soviet Nuclear Testing* (Cambridge, Mass.: Report for Project on Managing the Atom, Belfer Center for Science and International Affairs, Harvard Kennedy School, August 15, 2013), <http://belfercenter.ksg.harvard.edu/files/Plutonium%20Mountain-Web.pdf> (accessed March 8, 2014).

containing tons of low-grade HEU and three tons of better-than-weapon-grade plutonium. This material was packaged in massive containers and shipped to a secure site far from the Caspian Sea, where it had been stored.²⁷

In recent years, including during the four-year effort, many countries have taken action to strengthen cybersecurity for nuclear facilities. The Stuxnet virus used to sabotage Iran's centrifuge facility at Natanz highlighted the threat of cyberattack on nuclear facilities in a very public way.²⁸ Three main forms of cyber attack are particularly important for nuclear security. First, a cyber attack might be used to sabotage a nuclear facility, as Stuxnet reportedly did. In the case of Iran, the attack was intended to inflict damage on centrifuge cascades and slow Iran's enrichment progress, not to cause the spread of radioactive material. A similar kind of cyber attack on a nuclear power plant could have the objective of causing a major radioactive release and have far more damaging results. Second, a cyber attack might contribute to a more conventional theft or sabotage attempt—for example by confusing or disabling alarm and assessment systems or unlocking doors. Third, adversaries might use cyber weaknesses to get access to sensitive nuclear information—ranging from information about making nuclear weapons to information about nuclear security systems and their weaknesses. Even before Stuxnet, regulators in the United States and several other countries were establishing new requirements for cyber defenses and vulnerability assessments, and operators were developing new approaches—though the ever-changing nature of the threat made defense an extraordinary challenge. The IAEA published its technical guidance on computer security at nuclear facilities in 2011, and a number of countries are drawing from that guidance.²⁹ The World Institute for Nuclear Security (WINS) has also produced a best practice guide on the matter. Overall, it is fair to say that, in many countries with extensive nuclear establishments, cybersecurity for nuclear assets is significantly better today than it was before the four-year effort began—though there is still a great deal to be done.³⁰

These actions are welcome—though the resulting reductions in the overall risk of nuclear theft or sabotage range from large to small. Other countries have also taken steps to upgrade security

²⁷ US Department of Energy, National Nuclear Security Administration, “NNSA Secures 775 Nuclear Weapons Worth of Weapons-Grade Nuclear Material from BN-350 Fast Reactor in Kazakhstan” (Washington, D.C.: NNSA, November 18, 2010), <http://nnsa.energy.gov/mediaroom/pressreleases/bn35011.18.10> (accessed March 8, 2014). As we have noted previously, NNSA's headline is incorrect in two respects: the material was not remotely enough for 775 nuclear weapons (NNSA is using the IAEA's “significant quantity” figures incorrectly), and most of it is not close to being weapon-grade, but rather is medium-enriched uranium that would be quite difficult to make into a nuclear bomb without further enrichment. The material likely had an average enrichment in the range of 25 percent prior to irradiation and has much lower enrichments now. The material is embedded in spent fuel and would require reprocessing to recover it for use in nuclear weapons, though it no longer has a radiation field that would protect it from theft. For a more detailed critique of NNSA's repeated assertion on this point, see Eben Harrell's comment in the comments section below Ferenc Dalnoki-Veress, Jeffrey Lewis, and Miles Pomper, “Significantly Wrong on Significant Quantities,” March 1, 2012, <http://lewis.armscontrolwonk.com/archive/5028/significantly-wrong-about-significant-quantities> (accessed March 8, 2014).

²⁸ For a detailed journalistic account, see David Sanger, *Confront and Conceal: Obama's Secret Wars and Surprising Use of American Power* (New York: Crown, 2012), pp. 118–225.

²⁹ International Atomic Energy Agency, *Computer Security at Nuclear Facilities* (Vienna: IAEA, 2011), http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1527_web.pdf (accessed March 8, 2014). Several additional guidance documents on computer security are in development.

³⁰ The IAEA's nuclear security conference in July 2013 featured a panel on cybersecurity, with perspectives from the United States, South Korea, Pakistan, the Netherlands, and Brazil.

measures at their nuclear sites, but no comprehensive record of all the steps that have been taken exists.

Rather than attempting a comprehensive global assessment of all changes in nuclear security standards worldwide, below we describe change in three classes of stockpiles we identified in our 2012 report as posing high remaining risks for theft of nuclear weapons or weapons-usable nuclear material—stocks in Pakistan, in Russia, and at those HEU-fueled research reactors with enough high-quality HEU for a gun-type bomb at a single site.³¹ The four-year effort saw significant changes in each of these areas.

Pakistan

In Pakistan, there is a frightening nexus of nuclear weapons and severe terrorist threats. Pakistan substantially increased security for its nuclear stockpiles after its 1998 nuclear tests and the revelation of the global black-market nuclear technology network led by A.Q. Khan. The Pakistani government created the “Strategic Plans Division” (SPD) to oversee security and management of its nuclear weapons, and put a wide range of new controls in place. One Pakistani official has asserted that 25,000 troops are assigned to guarding Pakistan’s nuclear weapons.³² With help from the IAEA, Pakistan has established a major Nuclear Security Training Center, which a British expert has described as “a model example of what a centre is and should be undertaking in terms of nuclear security training, provision of technical advice and education to a state’s nuclear security ‘competent authorities’.”³³ In our recent survey, Pakistan’s nuclear security expert reported “dramatic” changes in the organizations governing nuclear security; in the numbers, training, and equipment of guard forces; in approaches to screening personnel; in requirements for nuclear material accounting; and in approaches to strengthening security culture, and substantial changes in every other aspect of nuclear security covered in the survey.³⁴ Nevertheless, Pakistan’s nuclear security systems face greater threats they must defend against—both from terrorists attacking facilities from the outside and from potentially sympathetic insiders—than the systems of any other country.

The United States has provided substantial assistance for Pakistan’s nuclear security, reportedly amounting to well over \$100 million.³⁵ This cooperation has been complicated by mutual

³¹ Bunn, Harrell, and Malin, *Progress on Securing Nuclear Weapons and Materials*, pp. 5–12.

³² Finance Minister Ishaq Dar asserted that a “special security force of 25,000 personnel, who have been specially trained and provided sophisticated weapons, has been deployed to protect (the nuclear assets).” See “Pakistan Says 25,000 Guards Watching Nukes,” *Global Security Newswire*, June 25, 2013. By another account, the total strength of the “security division” of the National Command Authority amounts to 20,000; not all of these personnel may be assigned to guard duties at any particular time. See Naeem Salik and Kenneth N. Luongo, “Challenges for Pakistan’s Nuclear Security,” *Arms Control Today* (March 2013), http://www.armscontrol.org/act/2013_03/Challenges-for-Pakistans-Nuclear-Security (accessed March 6, 2013).

³³ See Alan Keyes, “Study of the Nuclear Security Centers of Excellence for the Carnegie Corporation of New York” (London: King’s College London Center for Science & Security Studies, April 2012), http://www.stanleyfoundation.org/nuclearsecurity/Nuclear_Security_COE_study_final.pdf (accessed March 6, 2014), p. 12. A discussion of Pakistan’s center appears on pp. 55-58. For an official description, see Pakistan Nuclear Regulatory Authority, “Nuclear Security Action Plan” (Islamabad: no date), <http://www.pnra.org/nsap.asp> (accessed March 6, 2014).

³⁴ Bunn and Harrell, *Threat Perceptions and Drivers of Change in Nuclear Security*, p. 9.

³⁵ David E. Sanger, “Pakistan Strife Raises U.S. Doubt on Nuclear Arms,” *New York Times*, May 3, 2009, <http://www.nytimes.com/2009/05/04/world/asia/04nuke.html> (accessed February 24, 2014).

mistrust and suspicion.³⁶ Pakistani nuclear officials fear that the United States might try to seize their nuclear arsenal, and have made clear that they see the United States and India as bigger threats to their stockpile than terrorists or thieves.³⁷ Pakistan does not allow US experts to visit its nuclear facilities or even know where they are located, making the cooperation much more difficult than it is in countries where US experts can visit and review the security at the facilities themselves.³⁸ While Pakistani officials have acknowledged participating in nuclear security cooperation with the United States, both countries have kept all specifics secret, making it difficult to judge how much has been accomplished.³⁹

Several major trends related to nuclear security have been underway in Pakistan during the four-year nuclear security effort:

- **Fearsome terrorist threats continue.** Terrorist groups within Pakistan have remained highly capable and perhaps even increased in strength. They have shown their willingness and ability to attack heavily defended targets, with major assaults on Pakistan's Army headquarters in 2009 (where they penetrated the site, seized hostages, and were in control of at least one building for hours); the Mehran air base in 2011 (where they penetrated the site and destroyed several military aircraft, and it again took many hours before they were defeated); and the 2012 attack on the Minhas airbase (where, again, assailants penetrated the base, damaged an aircraft, and fought for hours before Pakistani forces could defeat them).
- **Major nuclear buildup underway.** Pakistan is expanding its nuclear forces more rapidly than any other country in the world, and is shifting to construction of tactical nuclear weapons.⁴⁰ These smaller, more mobile systems would be dispersed early in a crisis, possibly

³⁶ For a discussion, see, for example, David Sanger, *The Inheritance: The World Obama Confronts and the Challenges to American Power* (New York: Harmony, 2009), pp. 177–179.

³⁷ Immediately after the US raid that killed Osama bin Laden, for example, Pakistani legislators called for inquiries, asking, as the *New York Times* put it, whether the military “could defend Pakistan’s borders and its nuclear arsenal from being snatched or attacked by the United States or India.” Jane Perlez, “Pakistani Army, Shaken by Raid, Faces New Scrutiny,” *New York Times*, May 4, 2011. One account asserted that the commander in chief of the Pakistani Army directed that nuclear weapons be moved to make them more difficult for the United States to find and seize. See Jeffrey Goldberg and Marc Ambinder, “The Pentagon’s Secret Plans to Secure Pakistan’s Nuclear Arsenal,” *Global Security Newswire*, November 9, 2011, <http://www.nti.org/gsn/article/the-pentagons-secret-plans-to-secure-pakistans-nuclear-arsenal/> (accessed March 8, 2014). In a visit shortly after the Abbottabad raid, Secretary of State John Kerry sought to assuage these Pakistani concerns, saying the United States had “no designs” on Pakistan’s nuclear stockpile. See Mariana Baabar, “Time to Press the ‘Reset’ Button on Pak-US Ties: Kerry,” *The News*, May 17, 2011, <http://www.thenews.com.pk/Todays-News-13-6036-Time-to-press-> (accessed March 8, 2014). For a Pakistani account arguing that such concerns are unjustified, see Shireen M. Mazari, “Can United States Seize Pakistan’s Nukes? Separating Myth and Reality in the Media Campaign Against Pakistan” (Islamabad: Project Pakistan 21, May 2011), <http://www.projectpakistan21.org/wp-content/uploads/2011/05/Can-US-Seize-Pak-Nukes-PP21-May11.pdf> (accessed May 8, 2014).

³⁸ See Sanger, *The Inheritance*, p. 177. An article co-authored by a retired Strategic Plans Division general confirmed that Pakistan insists on “nonintrusiveness and maintaining secrecy related to its nuclear weapons and their locations.” See Kenneth N. Luongo and Brig. Gen. (Ret.) Naeem Salik, “Building Confidence in Pakistan’s Nuclear Security,” *Arms Control Today*, (December, 2007), http://www.armscontrol.org/act/2007_12/Luongo.asp.

³⁹ See, for example, Nirupama Subramanian, “Pakistan Accepted U.S. Help on N-Plants,” *The Hindu*, June 22, 2006.

⁴⁰ Pakistan only recently started up its second plutonium production reactor; a third is either complete or nearing completion; and a fourth is under construction. See David Albright and Paul Brannan, “Pakistan Appears to

with pre-delegation of launch authority (or at least physical capability of use) to lower levels of command—clearly increasing the danger of both nuclear theft and unauthorized use in moments of crisis.⁴¹ (Pakistani officials have reported that they use some form of locks on their nuclear weapons similar to US Permissive Action Links, but the specifics are not publicly known.)⁴²

- **Continuing conflict with India.** Pakistan’s conflict with India has remained unresolved, with border violence over Kashmir spiking in 2013, raising new fears that some unexpected event—such as a major terrorist attack in India—could provoke a nuclear crisis.⁴³ If such a crisis were severe, nuclear weapons could be distributed to frontline forces, leading to road shipments and dispersal from secure sites that could increase the risks of theft and terrorism—in addition to larger danger of a nuclear conflict. Indeed, terrorists might plan their attacks to cause such an effect.
- **Improving nuclear security.** Improvements in Pakistan’s nuclear security arrangements appear to be continuing. The force that guards Pakistan’s nuclear stockpiles appears to have grown rapidly in recent years.⁴⁴ The new training center is providing a cadre of specially trained people for guarding nuclear facilities. President Obama reportedly expanded US investments in Pakistani nuclear security after taking office.⁴⁵

Management of nuclear security in Pakistan is now going through a transition. Retired Lieutenant General Khalid Kidwai led the SPD, first in uniform, then as a civilian after his military retirement, from its inception in 2000 until late 2013. He retired from the SPD in December 2013 and was replaced by Lieutenant General Zubair Mahmood Hayat. It is too soon to tell how Hayat’s approach will differ from Kidwai’s; US officials will have to invest again in building a partnership with the SPD’s new leader.

be Building a Fourth Military Reactor at the Khushab Nuclear Site” (Washington, D.C.: Institute for Science and International Security, February 9, 2011), http://isis-online.org/uploads/isis-reports/documents/Fourth_Khushab_Reactor_9Feb2011.pdf (accessed March 8, 2014); Sanjeev Miglani, “Pakistan Builds Low Yield Nuclear Capability, Concern Grows,” *Reuters*, May 15, 2012.

⁴¹ Vipin Narang, “Pakistan’s Nuclear Posture: Implications for South Asian Stability” (Cambridge, Mass: Belfer Center for Science and International Affairs, Harvard Kennedy School, January 2010), http://belfercenter.ksg.harvard.edu/publication/19889/pakistans_nuclear_posture.html (accessed March 8, 2014).

⁴² Peter Wonacott, “Inside Pakistan’s Drive to Guard Its A-Bombs,” *The Wall Street Journal*, November 29, 2007, <http://online.wsj.com/news/articles/SB119629674095207239> (accessed March 8, 2014).

⁴³ Annie Gowen, “Pakistan, India, Spar in Kashmir in Worst Border Violence in Years,” *Washington Post*, September 12, 2013.

⁴⁴ Salik and Luongo, “Challenges for Pakistan’s Nuclear Security.”

⁴⁵ Sanger, *Confront and Conceal*, p. 62.

Incident: Attack on Pakistani Military Headquarters, 2009

On the morning of October 10, 2009, ten militants stormed Pakistani military headquarters in Rawalpindi, one of the most heavily guarded sites in Pakistan.¹ The attackers had military uniforms (and possibly forged IDs), along with assault weapons, grenades, and explosives. By one account, they operated in two teams from different directions.² The initial gun battle lasted 45 minutes, after which the remaining militants seized a building and some 40 hostages. The attackers' ability to overcome the site defenses and the speed with which they seized the building suggested they may have had insider information on the site and its security arrangements. Ultimately, it took the Pakistani army some 18 hours to retake the building and end the hostage crisis. In the end, nine of the attackers were killed and one captured; but the militants had struck a major blow against the Pakistani military, showing the vulnerability even of Army headquarters, while killing a brigadier general, a lieutenant colonel, and a dozen others.

There have been at least two similar assaults on heavily defended military targets since then. In May 2011, militants attacked the Pakistani naval base at Mehran, reportedly wearing military fatigues and with insider knowledge of the base, and succeeded in destroying two aircraft, killing ten Pakistani soldiers, and holding off Pakistani military personnel for some 15 hours. They were reportedly equipped with automatic weapons, rocket-propelled grenades, sniper rifles, and night-vision goggles; Pakistani military witnesses described them as impressively trained—"excellent shots—as good as

¹ For discussions of the Rawalpindi attack, see, for example "Pakistani Army Raid Frees Hostages," *BBC News*, October 11, 2009, http://news.bbc.co.uk/2/hi/south_asia/8301175.stm (accessed March 10, 2014); Hassan Abbas, "Deciphering the Attack on Pakistan's Army Headquarters" in *Foreign Policy: The AfPak Channel*, ed. (July 1, 2012, 2009), http://afpak.foreignpolicy.com/posts/2009/10/11/deciphering_the_attack_on_pakistan_s_army_headquarters (accessed March 10, 2014); Jane Perlez, "Pakistani Police Had Warned Army About Raid," *New York Times*, October 11, 2009, http://www.nytimes.com/2009/10/12/world/asia/12pstan.html?_r=2 (accessed March 10, 2014); Shaun Gregory, "Terrorist Tactics in Pakistan Threaten Nuclear Weapons Safety," *CTC Sentinel*, Vol. 4, No. 6 (June 2011), pp. 4-7; Charles P Blair, *Anatomizing Non-State Threats to Pakistan's Nuclear Infrastructure: The Pakistani Neo-Taliban*, Terrorist Analysis Report No. 1 (Washington, D.C.: Federation of American Scientists, June, 2011), http://www.fas.org/pubs/_docs/Terrorism_Analysis_Report_1-lowres.pdf (accessed March 10, 2014), p. 145.

² Abbas, "Deciphering the Attack on Pakistan's Army Headquarters."

India

Like Pakistan, India has a relatively small stockpile of nuclear weapons and military weapons-usable nuclear material at a moderate number of sites, which are believed to be heavily guarded.⁴⁶ Unlike Pakistan, India has a substantial civilian plutonium program. New reprocessing plants with reported capacities of 100 tons of spent fuel per year opened at Kalpakkam in 1998 and at Tarapur in 2011, and another is expected to start operations at Kalpakkam in 2014.⁴⁷ A new 500 megawatt-electric (MWe) Prototype Fast Breeder Reactor (PFBR) is also expected to

⁴⁶ For a summary of the limited available information as of the early 2000s, see Nathan Busch, *No End in Sight: The Continuing Menace of Nuclear Proliferation* (Lexington, KY: University Press of Kentucky, 2004). Some additional detail was provided in presentations at International Atomic Energy Agency, "IAEA Regional Training Course on Security for Nuclear Installations," Mumbai, India, 11–20 May 2003. For a summary of India's stockpiles, see International Panel on Fissile Materials, *Global Fissile Materials Report 2013: Increasing Transparency of Nuclear Warhead and Fissile Material Stocks as a Step Toward Disarmament* (Princeton, N.J.: International Panel on Fissile Material, 2013), <http://fissilematerials.org/library/gfmr13.pdf> (accessed March 10, 2014), pp. 10, 1314, 21–22.

⁴⁷ International Panel on Fissile Materials, *Global Fissile Materials Report 2013*, p. 22.

Incident: Attack on Pakistani Military Headquarters, 2009 (Cont.)

any we have.”³ And in August 2012, nine heavily armed terrorists attacked the Minhas air base (which has sometimes been reported to house nuclear weapons, though Pakistani officials say it does not), succeeding in destroying an aircraft, killing two defenders, and shooting the base commander in the shoulder.⁴

These were non-nuclear attacks, but with the right tactics and enough firepower, a similar attack—a terrorist assault on a heavily guarded facility, involving sophisticated planning, the use of deception (including, by some accounts, not just the uniforms but forged identifications), attackers willing and eager to sacrifice their lives, and probably insider knowledge of the security arrangements—would pose a serious threat to a nuclear weapons or nuclear materials site.

These incidents offer several lessons:

- Large numbers of disciplined, well-armed, well-trained attackers, prepared to die in their assault, are a credible threat in Pakistan, where highly capable terrorist groups operate, and sometimes have ties to those in Pakistani security services.
- Terrorists do sometimes choose to attack heavily guarded targets—and when they do, they are able to bring a level of force they think will be sufficient to overcome the defenses.
- Adversaries may use deception—such as official uniforms—to confuse initial defenses and give them at least a momentary advantage.
- Response forces at nuclear facilities should be equipped with night-vision goggles in case adversaries attack at night and have such equipment.
- In some situations, it may take a substantial time for response forces to arrive, plan their response, and defeat the adversaries.

³ See, for example, Syed Shoaib Hasan, “‘New Kind of Militant’ Behind Pakistan Karachi Attack,” *BBC News*, May 25, 2011, <http://www.bbc.co.uk/news/world-south-asia-13508864> (accessed March 10, 2014).

⁴ See, for example, Qasim Nauman, “Militants Attack Major Pakistan Air Base; Nine Killed,” *Reuters*, August 16, 2012.

start operation in the fall of 2014.⁴⁸ In the future, India has plans for large-scale breeding, reprocessing, and recycling of plutonium fuels, and eventually breeding of U-233 from thorium.⁴⁹

India’s approach to nuclear security is highly secretive, and little is publicly known about India’s nuclear security arrangements.⁵⁰ The threats India’s nuclear security systems must confront

⁴⁸ International Panel on Fissile Materials, *Global Fissile Materials Report 2013*, p. 22.

⁴⁹ See World Nuclear Association, “Nuclear Power in India” (London: World Nuclear Association, February 2014), <http://www.world-nuclear.org/info/Country-Profiles/Countries-G-N/India/> (accessed March 7, 2014). For a critique of India’s plans and practices to date, see M.V. Ramana, *The Power of Promise: Examining Nuclear Energy in India* (New York: Penguin, 2013).

⁵⁰ For a summary that notes this lack of transparency, see Nuclear Threat Initiative and Economic Intelligence Unit, *NTI Nuclear Materials Security Index*, January 2012, p. 29.

For an Indian response, which also emphasizes India’s approach of making very little information publicly available, see Sandeep Dikshit, “Transparency No Index of Nuclear Security, Says India,” *The Hindu*, January 12, 2014.

appear to be significant—though not as great as the threats that exist in Pakistan.⁵¹ India faces challenges both from domestic terrorist organizations and from attacks by terrorist organizations based in Pakistan, such as the 2008 Mumbai attack and the 2001 assault on India’s parliament. David Headley, who carried out reconnaissance for the Mumbai attacks, reported that his Lashkar-e-Taiba handlers asked him to carry out reconnaissance at Indian nuclear facilities, including the Bhabha Atomic Research Centre, which handles significant quantities of plutonium.⁵² India also deployed special commandos to help protect the Indira Ghandi Atomic Research Centre at Kalpakkam, another site with substantial quantities of plutonium, after a warning from Indian intelligence agencies. In late 2013, a captured Indian terrorist told interrogators that he had asked terrorist accomplices in Pakistan to provide a nuclear weapon for an attack against the Indian city of Surat.⁵³ In addition to these risks, India also confronts significant insider corruption, though corruption in India is thought to be somewhat less severe than it is in Pakistan or Russia.⁵⁴

Like the United States and many other countries, India requires facilities to be protected against a set of risk scenarios specified in a DBT. In a recent survey, the Indian expert participating indicated that nuclear security requirements in India have become much more stringent in the last 15 years, primarily in reaction to domestic incidents, and that in particular there have been dramatic changes in the DBT.⁵⁵ A special security agency, the Central Industrial Security Force (CISF), guards both nuclear installations and other especially dangerous or sensitive industrial facilities. Indian experts report that India performs systematic vulnerability assessments in designing physical protection systems for nuclear facilities and makes use of some modern security technologies, including access controls and various types of intrusion detectors.⁵⁶ As of the early 2000s, resources available for physical protection appeared to be limited, however, and in some cases physical protection systems were aging and had some important weaknesses.⁵⁷

It is likely that India has taken significant steps to improve security for nuclear materials and facilities after the deadly 2008 attack on Mumbai, as part of the broader effort to protect critical infrastructure after that attack, but India has provided little public information about such improvements. Some additional steps are still underway, generally embedded within broader efforts

⁵¹ For a useful summary of the threat in India, see Rajeswari Pillai Rajagopalan, Tobias Feakin, Jennifer Cole, Rahul Prakash, Wilson John, and Andrew Somerville, *Chemical, Biological, and Radiological Materials: An Analysis of Security Risks and Terrorist Threats to India* (New Delhi: Observer Research Foundation and Royal United Services Institute, 2012).

⁵² National Investigation Agency, Government of India, *Interrogation Report of David Coleman Headley* (New Delhi: NIA, 2010), p. 66, <http://info.publicintelligence.net/NIA-HeadleyInterrogation.pdf> (accessed March 8, 2014).

⁵³ See Neeraj Chauhan, “Indian Mujahideen Wanted to Nuke Surat, Yasin Bhatkal Tells Cops,” *Times of India*, December 30, 2013, <http://timesofindia.indiatimes.com/india/Indian-Mujahideen-wanted-to-nuke-Surat-Yasin-Bhatkal-tells-cops/articleshow/28116663.cms> (accessed March 8, 2014).

⁵⁴ In 2013, Transparency International ranked India 94th out of 177 states included in its index for the severity of corruption, while Pakistan and Russia were tied at 127th. See Transparency International, *Corruption Perceptions Index 2013* (Berlin: TI, 2013), <http://www.transparency.org/cpi2013/results> (accessed March 8, 2013).

⁵⁵ Bunn and Harrell, *Threat Perceptions and Drivers of Change*, pp. 26–31. The reported changes in most other elements of nuclear security were much more modest.

⁵⁶ Presentations to International Atomic Energy Agency and Bhabha Atomic Research Centre, “IAEA Regional Training Course on Security for Nuclear Installations,” Mumbai, India, May 11–20, 2003. Since then, India has hosted IAEA regional training courses almost every year.

⁵⁷ Interview with a US expert who toured the physical protection system at an Indian power reactor, at Indian invitation, in 2003. Personal communication, July 2003.

to improve its nuclear energy governance. First, in 2011 India announced that it would replace its Atomic Energy Regulatory Board (AERB) with a new Nuclear Safety Regulatory Authority, which would be fully independent of the Department of Atomic Energy. The AERB, which had been responsible for regulating both safety and security of civilian nuclear facilities, reports to a committee chaired by the chairman of the Atomic Energy Commission, and hence was not fully independent—an arrangement sharply criticized in a recent report by India’s Comptroller and Auditor General.⁵⁸ The Indian government reportedly also plans to establish a new group responsible for regulating military nuclear activities, which have been self-regulated.⁵⁹ As of early 2014, however, legislation establishing the new regulatory agency had not been approved.

Second, India has established the Global Centre for Nuclear Energy Partnership (GCNEP), which will provide research and development, training, and technical support for nuclear energy, nuclear safety, and nuclear security.⁶⁰ In particular, GCNEP includes a “School of Nuclear Security”; in early 2013, GCNEP held the first Indian training course in physical protection “exclusively for security personnel”.⁶¹

Like Pakistan, India has been an active participant in the nuclear security summit process, and has emphasized that, while nuclear security is primarily a national responsibility, there are “benefits to be gained” from “sustained and effective international cooperation.” Nevertheless, in sharp contrast to Pakistan, India and the United States have not established in-depth cooperation on nuclear security, despite the nuclear rapprochement represented by the 2005 India nuclear deal. In recent years, however, the two countries signed an accord on cooperation on GCNEP, Indian nuclear security experts toured a number of US facilities, and the two sides agreed on priority areas for further technical exchanges. Moreover, the two countries are cooperating on radiological source security.⁶²

Given the limited information available about India’s nuclear security measures, it is difficult to judge the balance between the threat in India and the security measures to protect against it. India’s long-standing isolation from much of the rest of the nuclear world (now beginning to decrease), its resistance to in-depth cooperation on nuclear security or review of its nuclear security measures, and the substantial threats that exist suggest that the risk of theft or sabotage in India may be uncomfortably high.

⁵⁸ Comptroller and Auditor General of India, *Performance Audit on Activities of Atomic Energy Regulatory Board* (Department of Atomic Energy), Report No. 9 of 2012–2013 (Delhi: CAG, 2012).

⁵⁹ The government’s proposed legislation refers to the establishment of “other regulatory bodies for the purpose of national defence and security.” *The Nuclear Safety Regulatory Authority Bill, 2011*, Bill No. 76 of 2011 (New Delhi: Government of India, 2011), <http://www.prsindia.org/uploads/media/Nuclear%20Safety/Nuclear%20Safety%20Regulatory%20Authority%20Bill%202011.pdf> (accessed March 8, 2014).

⁶⁰ For descriptions of GCNEP, see Keyes, “Study of the Nuclear Security Centers of Excellence,” pp. 46–47, and the GCNEP website, <http://www.gcnep.gov.in/index.html> (accessed March 8, 2014).

⁶¹ For a description, see the School’s website, <http://www.gcnep.gov.in/schools/snss.html> (accessed March 8, 2014). For a discussion of the recent training course, see GCNEP and Bhabha Atomic Research Centre, “National Training Course on Physical Protection of Nuclear Material and Nuclear Facilities” (Mumbai: GCNEP and BARC, 2013) <http://www.gcnep.gov.in/programs/details/NTC-PPofNMNF-Report.pdf> (accessed March 8, 2014).

⁶² For cooperation on GCNEP, see The White House, Office of the Press Secretary, “Fact Sheet on Nuclear Security” (Washington, D.C.: The White House, November 8, 2010), http://www.whitehouse.gov/sites/default/files/india-fact-sheets/Fact_Sheet_on_Nuclear_Security.pdf (accessed March 8, 2014).

Russia

Nuclear security in Russia has improved dramatically since the years immediately following the collapse of the Soviet Union. No longer are there gaping holes in fences, staff going unpaid for months at a time, guards leaving their posts to forage for food, or alarm systems shutting down because the facility could not pay its electric bill. Facilities with nuclear weapons, HEU, or separated plutonium are generally equipped with modern fences, intrusion detectors, barriers, access control systems, vaults, and accounting and control systems. It would now be a difficult job to steal nuclear material in Russia, requiring a sophisticated conspiracy.

Unfortunately, sophisticated conspiracies to steal valuable items continue to plague Russia, and corruption continues to be a serious problem, including in the nuclear complex. Russia continues to have far more locations with nuclear weapons, separated plutonium, or HEU than are used in other nuclear weapons states—and some significant security weaknesses remain.

Most of the major improvements in nuclear security in Russia took place before the four-year effort began. At a summit in Bratislava in 2005, after years of cooperative nuclear security improvement work, US President George W. Bush and Russian President Vladimir Putin agreed to a joint nuclear security initiative that included an accelerated push to complete upgrades by the end of 2008. As a result, the two sides completed upgrades at all of the nuclear weapon storage facilities and most of the weapons-usable material buildings where they had agreed to work together just before the four-year effort began. (A few dozen buildings remained after 2008, partly because Russia agreed to add additional buildings later, after the initial list for the Bratislava initiative had been agreed.) This cooperation continued through the previous major crisis in Russia's relations with the West—the war in Georgia in 2008. In short, the United States and Russia showed they could work together and accomplish steps that were vitally important to the security of both countries—and the world.

Despite the work done before the four-year effort began, the period since April of 2009 was an eventful time for nuclear security in Russia. Key trends and events included:

- **Russian government enthusiasm declines.** Long before the current crisis in Ukraine, Russian central government officials took an increasingly negative view of further US-Russian cooperation on nuclear security within Russia, arguing that the job was finished and there was no further need for this effort.⁶³ (Russian facilities and technical experts, however, often remained eager to cooperate and to get help with the costs of nuclear security improvements.)

⁶³ See, for example, Russia's remarkable national statements at the 2010 and 2012 nuclear security summits, which say, in essence, that there is no need for Russia to make any national commitments to improve nuclear security because what it is doing already is so effective. See "Memorandum of the Russian Federation for the 2012 Nuclear Security Summit" (Moscow: Office of the President of Russia, March 27, 2012), http://eng.news.kremlin.ru/ref_notes/80 (accessed March 8, 2014). We believe this view is incorrect, but it is widespread. Recently, one of Russia's leading nonproliferation nongovernment organizations published a study authored by experts with long experience in US-Russian nuclear security cooperation, which argued that "Bilateral efforts in the area of bolstering the security of nuclear ammunition and nuclear industry facilities in Russia using American assistance must come to an end; all the objectives in this area have been achieved, and there is no scope for further cooperation." See Dauren Auben, Artem Blashchanitsa, Evgeny Buzhinsky, Dmitry Kovchegin, and Vladimir Orlov, *Prospects for International Cooperation in WMD Nonproliferation and Nuclear Security* (Moscow: PIR Center, September 2013).

- **Cooperative upgrades continue.** US-Russian cooperation on security and accounting upgrades continued, though with some important delays and difficulties. Russia and the United States cooperated to complete upgrades on 32 buildings containing HEU or plutonium, bringing the total to 218 of 229 planned.⁶⁴ They were unable to finish the last 11 buildings because of delays in getting contracts approved in the midst of the transition from the old cooperative threat reduction agreement to the new MNEPR accord. Indeed, as of March 2014, most US-Russian nuclear security cooperation had been on hold for a year, and the crisis in Ukraine was raising concerns over whether resumption would be slowed further.⁶⁵ Beyond the building upgrades, the two sides completed a centralized management system for logistical support for all the upgraded security equipment at nuclear warhead sites; replaced outdated security equipment at many sites; completed an upgraded perimeter for the guarded area at one of Russia’s nuclear weapon design labs; and made a number of further improvements in protection against insider theft, among many other improvements.⁶⁶
- **New forum established.** The United States and Russia established a nuclear energy and nuclear security working group, reporting to the two presidents, under the leadership of Deputy Secretary of Energy Daniel Poneman and Rosatom CEO Sergei Kirienko. In particular, the group includes a joint working group on HEU minimization, established in April 2013, which is working to remove HEU entirely from several locations in Russia.⁶⁷
- **Regulations modified.** Russia issued a number of strengthened nuclear security regulations. Most importantly, perhaps, after many years of interagency review and debate, a revised version of the “Basic Rules on Nuclear Material Control and Accounting” (known by its Russian acronym, OPUK) finally went into force in 2012.⁶⁸

⁶⁴ For the 218 buildings completed figure, see US Department of Energy, *FY 2014 Congressional Budget Request: National Nuclear Security Administration*, Vol. 1, DOE/CF-0084 (Washington, D.C.: DOE, April, 2013), <http://energy.gov/sites/prod/files/2013/04/f0/Volume1.pdf> (accessed March 10, 2014), pp. DN-81. Interviews with NNSA officials in January 2014 confirmed that this is still the figure.

⁶⁵ See, for example, Douglas P. Guarino, “U.S. Nuclear Security Efforts in Russia Stalled Amid Ongoing Ukraine Crisis,” *Global Security Newswire*, March 5, 2014.

⁶⁶ See, for example, US Department of Energy, *FY 2014 NNSA Budget Request*, pp. 86–106.

⁶⁷ This subgroup is mentioned in “Joint Statement of the Co-Chairs of the Nuclear Energy and Nuclear Security Working Group of the Bilateral US-Russian Presidential Commission” (Washington, D.C.: DOE, June 27, 2013), <http://energy.gov/articles/joint-statement-co-chairs-nuclear-energy-and-nuclear-security-working-group-bilateral-us> (accessed March 8, 2014).

⁶⁸ The new rules require the use of uniquely identifiable tamper-indicating devices, and statistical analysis of any differences between measurements of the nuclear material on hand and what the records say should be there. Interview with Russian nuclear official, June 2013.

Overall, while nuclear security in Russia is substantially improved, there remain some weaknesses that could be exploited. For example:

- **Nunn-Lugar agreement replaced with a very different agreement.** The Nunn-Lugar agreement that had provided the legal foundation for a broad spectrum of arms reduction, security, and nonproliferation work with Russia expired in June 2013, and the two sides replaced it with a bilateral protocol under the umbrella of the Multilateral Nuclear Environmental Program in the Russian Federation (MNEPR). The new protocol is narrower, excluding past activities such as strategic arms dismantlement and chemical weapons destruction—and it excludes work with the Ministry of Defense entirely, leaving no legal basis for continued cooperation on security for nuclear weapons or naval fuel. While upgrades at those sites were completed, many issues related to sustainability, training, regulation, and security culture remain to be addressed. Some of the equipment purchased at the beginning of cooperation programs is past its lifetime and will need to be replaced. The new protocol, however, provides an explicit legal foundation for several activities that never had such a legal basis before, such as work on consolidating HEU and on converting HEU-fueled reactors to LEU.⁶⁹
- **Funding and sustainability.** Comments from a range of experts at Russian nuclear sites suggest that there are continuing problems with the funding needed to sustain modern nuclear security systems— particularly at research facilities with limited resources.⁷⁰
- **Security culture.** Security culture—the habit among all relevant staff of making effective security a priority— remains a problem worldwide, including in both the United States and Russia—as evidenced in the United States by the Y-12 incident. In Russia, many nuclear experts fundamentally do not believe that nuclear theft and terrorism are serious problems—yet belief in the threat is the foundation for a strong security culture.⁷¹ The United States and Russia have a joint security culture working group, and many Russian sites now have designated coordinators whose job is to strengthen the security culture at their sites (a novel innovation, not practiced elsewhere in the world), but there is more to be done.
- **Insider protection.** The insider threat is the most critical part of the nuclear security challenge. All of the known thefts of HEU or separated plutonium appear to have been perpetrated by, or with the help of, insiders.⁷² Russia continues to have a widespread problem of corruption and insider theft—though false accusations of corruption made for political

⁶⁹ For a description of the protocol, see “A New Legal Framework for US-Russian Cooperation in Nuclear Nonproliferation and Security” (Washington, D.C.: US Department of State, June 19, 2013), <http://www.state.gov/r/pa/prs/ps/2013/06/210913.htm> (accessed March 8, 2014).

⁷⁰ Many of the security systems installed with US assistance have limited lifetimes; in many cases, maintaining them requires an annual expenditure of roughly 10% of their initial cost. Some were installed over a decade ago (roughly their projected useful life).

⁷¹ Sergei Ivanov, then the Russian Minister of Defense, summed up a widely expressed Russian view in 2004, asserting that it was “impossible for there to be any loss” of plutonium or uranium, and that there had never been “a single case of so much as a gram being lost.” (This statement was clearly false, since there had been cases where individuals had been caught and confessed to their thefts.) Russian acceptance of cooperative threat reduction assistance, he said, “does not mean that nuclear materials are stored poorly.” See Svetlana Babaeva, “Responsible, Rational, With No Fear on His Face,” *Izvestia*, April 9, 2004 (trans. by What the Papers Say).

⁷² Matthew Bunn and Scott D. Sagan, “A Worst Practices Guide to Insider Threats: Lessons from Past Mistakes” (Cambridge, Mass.: American Academy of Arts and Sciences, March 2014).

purposes often make specific cases difficult to judge. The Russian military prosecutor general estimated that the cost to Russia of military corruption increased 450 percent in 2012 compared to 2011, and described how one manager of a defense factory had gone so far as to intentionally drive his own plant into bankruptcy, costing the Russian government some \$39 million.⁷³ The conviction of former Minister of Atomic Energy Yevgeny Adamov for stealing millions of dollars is only one of many indicators that this problem extends into the nuclear sector. In late 2010, for example, Major-General Victor Gaidukov, commander of a nuclear weapon storage site, was relieved of his duties for false income reports, and accused of corruption and theft; press reports suggest that Gaidukov's activities included stealing funds from US efforts to beef up nuclear safety and security.⁷⁴ In mid-2012, the director of the Siberian Chemical Combine, one of Russia's largest HEU and plutonium processing facilities, was arrested with other senior managers of the facility for large-scale corruption and embezzlement; over \$2 million in cash and three kilograms of gold bars were found in the director's home.⁷⁵ Russia's nuclear facilities have a range of protections in place against the insider threat, including portal monitors to detect nuclear material being removed and two-person or three-person rules, but there are vulnerabilities that insiders who understood the security system could exploit—as is also the case in the United States and many other countries.⁷⁶

- **Regulation.** In most cases, managers of nuclear facilities, seeking to accomplish their facilities' missions with limited resources, will only invest in expensive nuclear security measures if the government tells them they must. Hence, effective regulation is essential to strong and sustainable nuclear security. Nuclear security and accounting regulations in Russia have improved substantially, but Russian regulators exercise far less power than the agencies they are seeking to regulate, and both the regulations and their enforcement remain significantly weaker than their US counterparts. Here, too, corruption is a concern: in May 2008, a colonel in the Ministry of Interior charged with inspecting nuclear security arrangements was reportedly arrested for soliciting thousands of dollars in bribes to overlook violations he had uncovered in the closed nuclear city of Snezhinsk.⁷⁷
- **Material accounting.** Material accounting in Russia is dramatically improved compared to the 1990s, and will improve further as the new OPUK regulation is implemented. But at

⁷³ "Corruption Up 450% in a Year in Russian Military – Prosecutors," *RIA Novosti*, July 11, 2013, <http://en.ria.ru/crime/20130711/182183954/Corruption-up-450-in-a-Year-in-Russian-Forces--Prosecutors.html> (accessed March 8, 2014).

⁷⁴ "Russian General Dips Into U.S. Taxpayers' Pockets," *Nezavisimaya Gazeta*, December 27, 2010.; Russian Legal Information Agency, "General Discharged for False Income Disclosure Took \$333K in Bribes," February 20, 2012. After Gaidukov was fired, President Medvedev signed a decree relieving the commander of the force that guards and manages Russia's nuclear weapons, Col.-Gen. Vladimir Verkhovtsev, of his duties, though Verkhovtsev asserted publicly that the cases were unrelated. Gaidukov was initially acquitted in 2012, but the Military Board of the Russian Supreme Court overturned the acquittal and ordered a retrial. See Simon Saradzhyan, "Russia in Review" (Cambridge, Mass.: Belfer Center for Science and International Affairs, August 31, 2012), <http://belfercenter.org/publication/22290/> (accessed March 8, 2014).

⁷⁵ Russian press accounts of the case are summarized in "Russia: CEO of Enrichment Center Arrested for Massive Fraud," *Uranium Intelligence Weekly*, June 29, 2012.

⁷⁶ As just one example, Russia's new accounting and regulation includes a two-person rule requirement for storage areas but not for work in processing areas—where past experience suggests thefts are most likely to occur.

⁷⁷ "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].

Incident: Insider Conspiracy in Siberia, 2012

In June 2012, Vladimir Korotkevich, director of the Seversk Chemical Combine—one of Russia’s largest plutonium and HEU processing facilities—and two of his deputies were arrested for a corruption and embezzlement scheme that apparently netted them millions of dollars. A senior official of the Russian nuclear fuel cycle firm TVEL was also arrested.¹ Investigators reportedly found 80 million rubles (\$2.5 million) and three kilograms of gold bars in Korotkevich’s home.

Korotkevich and his co-conspirators are accused of a number of schemes involving kickbacks for coal supply for the Seversk facility and siphoning funds from metals trading. The accused have been held in pre-trial detention for over a year as the investigation continued.²

This case, of course, involved only money, not nuclear material. But an environment in which several individuals in the senior management of plutonium and HEU facilities are conspiring to enrich themselves to the tune of millions of dollars raises serious questions about the insider threat to nuclear materials.

This case, unfortunately, is not unique. In 2011, in response to the arrest of a deputy director of Rosatom and a number of co-conspirators for large-scale misappropriation of funds, a Rosatom spokesman made the remarkable statement that in just the past two years, 208 directors of Rosatom enterprises had been disciplined and 68 top managers fired for corruption.³

The two key lessons of this case are simple: multiple insiders working together are a real threat—and those insiders may even include the senior management of a facility. Nuclear security systems must be designed to protect against these kinds of threats.

¹ For a useful summary of myriad press reports on this case, see Gary Peach, “Russia: CEO of Enrichment Center Arrested for Massive Fraud,” *Uranium Intelligence Weekly*, June 29, 2012.

² “Imprisonment Term Extended for Former SCC Director General,” Nuclear.ru, September 13, 2013.

³ “Moscow City Court Releases on Bail Former Rosatom Head,” ITAR-TASS, November 12, 2012.

some sites, no one has physically measured the contents of each of the thousands of canisters of nuclear material built up over decades of operations for consistency with paper records—and even the new OPUK does not require analyses of trends in material unaccounted for that would be necessary to detect a thief stealing small amounts of nuclear material over time.⁷⁸

- **Guard forces.** For nuclear weapons, Russia uses a professional guard force in the 12th Main Directorate of the Ministry of Defence (or 12th GUMO, in its Russian acronym). But for weapons-usable nuclear material, a slow transition from poorly paid conscripts of the Ministry of Interior to more professional volunteer guard forces is still underway.⁷⁹

At the same time, there are elements of the Russian nuclear security approach that are likely to be more effective than the approaches used in the United States. In the United States, for example, guards are inside the fences waiting for a possible attack; in Russia, security services attempt to keep an eye on a substantial area around key nuclear sites, an approach they call operational

⁷⁸ Interviews with an expert from a major Russian nuclear site and a Russian regulatory expert, July 2012 and June 2013.

⁷⁹ Interviews with US and Russian participants in nuclear security cooperation, 2010–2014.

monitoring.⁸⁰ Russia also makes much more use of its intelligence services to keep an eye on insiders within nuclear facilities than is the case in the United States.

In short, despite the current crisis in US-Russian relations and the work already completed, there is still a compelling case for continued US-Russian cooperation on nuclear security—to continue to improve nuclear security in Russia, to exchange ideas that can improve nuclear security in both countries, to help improve nuclear security in third countries, and to develop improved nuclear security technologies and approaches.

Yet, both countries continue to face serious nuclear security challenges. Both can benefit from learning from the other’s experience in addressing these challenges. Hence, Russia and the United States should undertake an ongoing, long-term nuclear security cooperation effort, focused on helping other countries improve their nuclear security and on exchanging ideas, visits, and technologies to make further improvements in their own nuclear security arrangements.

HEU Research Reactors

The most important nuclear security improvements at HEU-fueled research reactors during the four-year effort were cases in which the HEU at these facilities was simply removed, either entirely or in substantial part. These are discussed below, in the section on reducing the number of sites with nuclear weapons and weapons-usable nuclear materials.

The four-year effort also included some substantial security upgrades at important HEU-fueled research reactors. The most dangerous facilities are those with enough high-quality HEU on-site to make a gun-type nuclear bomb.⁸¹ When the four-year effort began, there were only four such facilities in non-nuclear-weapon states (where security measures are sometimes less stringent than those in nuclear weapon states), and all of them saw significant improvements during the four-year effort:

- Ukraine eliminated all of its HEU, including almost 125 kilograms from the Kharkov Institute of Physics and Technology in Ukraine, which included enough 90 percent enriched oxide powder for a gun-type bomb.
- Belarus agreed to eliminate all of its HEU, and shipped out 88 kilograms of HEU from its Joint Institute for Power Engineering and Nuclear Research at Sosny, near Minsk, before suspending the deal after the United States, the European Union, and other countries imposed sanctions over serious election irregularities.⁸² Substantial security upgrades have

⁸⁰ This is similar in some respects to the continuous monitoring of the surrounding area that the DOE unit that performs secure transport attempts to implement. Craig Tucker, the head of that unit, emphasizes the importance of defeating the adversary *before* their attack begins: “When the bullets start flying, it’s a crapshoot and nobody can be sure how it’ll turn out.” See Roger Johnston, “Security Maxims” (Argonne, Ill: Argonne National Laboratory, September 2013), <http://www.ne.anl.gov/capabilities/vat/seals/maxims.shtml> (accessed March 8, 2014).

⁸¹ By “high quality,” we mean enriched to 70% U-235 or more, in pure metal or forms that could readily be converted to pure metal, not dispersed in other material (such as uranium-aluminum matrix research reactor fuel), and not irradiated enough to pose significant problems for processing and use.

⁸² This included 47 kilograms of fresh HEU and 41 kilograms of irradiated HEU. Data provided by NNSA of-

been completed for the remaining material during the four-year effort, including a new secure nuclear material storage vault.⁸³

- While South Africa agreed to ship all of its US-origin irradiated HEU reactor fuel to the United States, it has not decided to eliminate either its South African-origin spent reactor fuel or the high-quality HEU left over from its nuclear weapons program. But, as noted above, South Africa implemented major security upgrades at the Pelindaba site during the four-year effort, in part with US assistance. Unfortunately, South Africa and the United States have not made public the specifics of the new security measures implemented.
- Japan and the United States have been discussing the possibility of removing the HEU and plutonium at the Fast Critical Assembly at Tokai in Japan, and press reports suggest that Japan will announce at The Hague nuclear security summit that it plans to eliminate the plutonium at this facility.⁸⁴ Meanwhile, important security improvements have been implemented during the four-year effort, in part as a result of the new security regulations that went into force in the spring of 2012.

In addition, the general nuclear security improvements noted above for Belgium, Japan, the Netherlands, and Uzbekistan also apply to research facilities with HEU in those countries. Russia's improvements in physical protection and nuclear material accounting also applied to HEU-fueled research reactors. Pakistan's strengthened regulations apply primarily to its civilian infrastructure, which includes a small research reactor that used to be HEU-fueled and still stores a small amount of HEU. All of the countries whose experts participated in our survey have research facilities with HEU on-site (with that being the only weapons-usable nuclear material in seven of these countries), and all of them reported that nuclear security approaches had become either "much more stringent" (15 countries) or "modestly more stringent" (three countries) in the last 15 years—though how many of those changes took place during the four-year effort was not reported.

In addition, in the United States, NNSA's Global Threat Reduction Initiative (GTRI) financed installation of substantial security upgrades at all four of the NRC-licensed reactors that still use HEU fuel, going well beyond the security measures required by NRC regulations.⁸⁵

Progress in Reducing the Number of Sites and Buildings with Weapons-Usable Material

The only way to completely eliminate the risk that nuclear weapons or weapons-usable material will be stolen from a particular site is to remove the weapons or material, so that there is nothing left there to steal. Countries can achieve higher security at lower cost by protecting fewer

officials, December 2013. Over 200 kilograms of HEU remains in Belarus. For discussion, see for example, Miles Pomper, "Bringing Belarus Back to the Table," *WMD Junction*, September 20, 2011, http://cns.miis.edu/wmdjunction/110920_belarus.htm (accessed March 5, 2012).

⁸³ US Department of Energy, *FY 2014 NNSA Budget Request*, pp. DN-92.

⁸⁴ "Return Arms-Grade Plutonium: U.S.," *Japan Times*, Jan 27, 2014, <http://www.japantimes.co.jp/news/2014/01/27/national/return-arms-grade-plutonium-u-s/#.UuZUnXg8LCQ> (accessed February 24, 2014).

⁸⁵ Interview with NNSA official, December 2013.

places. Hence, consolidating nuclear weapons and materials to fewer locations is a key part of the nuclear security agenda.⁸⁶

Both nuclear weapons and weapons-usable nuclear material now exist in far fewer locations than they did in the 1970s and 1980s. But there is a long way to go. Unclassified estimates suggest that nuclear weapons are currently stored at over 100 sites in 14 countries (the nine states which possess nuclear weapons and five more countries in Europe where US nuclear weapons are stored). Weapons-usable nuclear material exists in hundreds of buildings in some 30 countries around the world.⁸⁷

Civilian HEU

Much of the consolidation effort in recent years has focused on civilian HEU.⁸⁸ The Washington and Seoul nuclear security summits agreed on the goal of minimizing the use of HEU, and in 2012 the Obama administration announced that the United States “is committed to eliminating the use of HEU in all civilian applications.”⁸⁹ Existing consolidation programs are making significant progress in reducing the number of civilian sites using HEU:

- Countries are eliminating their stocks. Twenty-seven countries have eliminated all of the weapons-usable nuclear material on their soil – roughly half of all the countries that ever possessed such material. Thirteen of these countries eliminated their stocks during the four-year nuclear security effort.⁹⁰ Most of these countries eliminated their stocks with help

⁸⁶ See Matthew Bunn and Eben Harrell, *Consolidation: Thwarting Nuclear Theft* (Cambridge, Mass.: Project on Managing the Atom, Harvard University, March, 2012), http://belfercenter.ksg.harvard.edu/files/Consolidation_Thwarting_Nuclear_Theft_corrected.pdf (accessed March 11, 2014).

⁸⁷ Nuclear Threat Initiative and Economist Intelligence Unit, *NTI Nuclear Materials Security Index*; International Panel on Fissile Materials, *Global Fissile Materials Report 2013*. The NTI Nuclear Materials Security Index lists 25 remaining countries with a kilogram or more of HEU or separated plutonium; in addition, Jamaica, Ghana, Syria, and Nigeria have just under a kilogram of this material in the cores of Slowpoke or Miniature Neutron Source Reactors (MNSRs), and Indonesia reportedly has just over a kilogram of HEU in waste from past nuclear activities.

⁸⁸ For an overview of many aspects of the issue, see Alan Kuperman, “Nuclear Terrorism and Global Security: The Challenge of Phasing out Highly Enriched Uranium,” *Routledge Global Security Studies*, (Routledge, 2013). For a recent presentation, see Frank von Hippel, “Progress Toward a Global Cleanout of Weapons-Usable Nuclear Materials,” Union of Concerned Scientists webinar, January 23, 2014.

⁸⁹ The White House, Office of the Press Secretary, “Fact Sheet: Encouraging Reliable Supplies of Molybdenum-99 Produced Without Highly Enriched Uranium” (Washington, D.C.: The White House, June 7, 2012), <http://www.whitehouse.gov/the-press-office/2012/06/07/fact-sheet-encouraging-reliable-supplies-molybdenum-99-produced-without-> (accessed March 8, 2014). For recommendations on how the summit process can contribute to HEU minimization, see Miles A. Pomper, “The 2012 Seoul Nuclear Security Summit and HEU Minimization” (Washington, DC: US-Korea Institute at SAIS, January 2012), http://uskoreainstitute.org/wp-content/uploads/2012/01/USKI_NSS2012_Pomper.pdf (accessed March 8, 2014).

⁹⁰ US Department of Energy, National Nuclear Security Administration, *The Four-Year Effort: Contributions of the Global Threat Reduction Initiative to secure the world’s most vulnerable nuclear material by December 2013* (Washington, D.C.: DOE/NNSA, December, 2013), <http://nnsa.energy.gov/sites/default/files/nnsa/12-13-inline-files/2013-12-12%20Year%20Effort.pdf> (accessed March 11, 2014). Twelve countries eliminated all of their HEU during the four-year effort: Austria, Chile, Czech Republic, Hungary, Libya, Mexico, Romania, Serbia, Taiwan, Turkey, Ukraine, and Vietnam. Sweden, which had eliminated all of its HEU earlier, eliminated all of its separated plutonium during the four-year effort, making a total of 13 countries that eliminated all their weapons-usable material during that period. In addition to Sweden, the 14 other countries where all HEU was removed before

Protecting Against Nuclear Sabotage

The four-year nuclear security effort endorsed in UN Security Council Resolution 1887 and at the Washington nuclear security summit in 2010 focused on nuclear weapons and the materials needed to make them. Since then, however, the global nuclear security dialogue has broadened. In the aftermath of the Fukushima nuclear disaster in 2011, protecting nuclear power plants and other major nuclear facilities from sabotage has become an important part of the global nuclear security agenda.¹

The Fukushima accident sent a powerful message about the huge scale of fear and economic damage a reactor meltdown could cause—and also highlighted the danger that terrorists could cause such a meltdown if they could destroy all power and emergency cooling for the reactors. Unfortunately, the International Atomic Energy Agency (IAEA) focused its response only on safety, ignoring the security implications.²

A number of countries, however, have included improvements in sabotage protection in their post-Fukushima action plans – starting with Japan, which imposed new requirements for operators to expand the zones in which they could detect intrusions, and to protect items that are essential for reactor safety but outside the formal protected area—such as electricity supplies.³ In the European Union (EU), while the “stress tests” after Fukushima focused only on safety, a separate working group on security recommended major improvements, and called for all EU member states with major nuclear facilities to request reviews of their security arrangements from the IAEA’s International Physical Protection Advisory Service (IPPAS).⁴

¹ Major international nuclear security instruments reflect this concern. The 2005 amendment to the physical protection convention, for example, broadens its coverage to include sabotage, and the 2011 revision to the IAEA’s physical protection recommendations greatly expands their coverage of protection against sabotage. For a discussion of both safety and security lessons from Fukushima, see Matthew Bunn and Olli Heinonen, “Preventing the Next Fukushima,” *Science*, Vol. 333 (September 16 2011), pp. 1580-1581.

² The IAEA leadership focused its ministerial meeting after Fukushima entirely on safety, along with the resulting action plan. See IAEA, “IAEA Action Plan on Nuclear Safety” (Vienna: IAEA, September 16, 2011), <http://www.iaea.org/newscenter/focus/actionplan/reports/actionplanns130911.pdf> (accessed March 8, 2014).

³ Naito, “Nuclear Security Regime in Japan.”

⁴ Ad Hoc Group on Nuclear Security, Report of the Ad Hoc Group on Nuclear Security, 10616/12 (Brussels: European Union, May 31, 2012).

from the US Global Threat Reduction Initiative (GTRI) and its predecessors. In all, at least some material has been removed from a total of 42 countries.

- Buildings and areas are being cleaned out. In addition to entire countries, there are particular buildings or material balance areas where all the weapons-usable nuclear material has been eliminated. Since 1996, GTRI and other US programs have helped eliminate all the weapons-usable nuclear material from more than 57 buildings or material balance areas outside the United States and Russia – at least 18 of these during the four-year effort.⁹¹

The sites where all HEU has been removed include 20 of the 29 sites where GTRI and its

the four-year effort are Brazil, Bulgaria, Colombia, Denmark, Georgia, Greece, Iraq, Latvia, Philippines, Portugal, Slovenia, South Korea, Spain, and Thailand.

⁹¹ Data on sites cleaned out during the four-year effort provided by NNSA officials, November 2013, updated for removal from Hungary in November 2013. For information on previous removals, see Bunn, Harrell, and Malin, *Progress on Securing Nuclear Weapons and Materials*, p. 13.

Protecting Against Nuclear Sabotage (Cont.)

There is a close link between nuclear safety and nuclear security; ultimately, a major nuclear facility cannot be adequately safe unless it is also secure. Effective plant management is essential to both. Many steps can help prevent damage to the reactor core and radioactive releases whether as a result of accidents or terrorism. In the United States, for example, post-Fukushima inspections found that many of the steps that the Nuclear Regulatory Commission (NRC) had ordered for protection against sabotage after 9/11—such as strengthened abilities to cope with fires and explosions, better emergency power supplies, and better ability to pump water into cores and spent fuel pools—were the same measures needed to improve safety. Because US reliability requirements for security equipment do not match those for safety equipment, inspectors found that much of this equipment was not actually working.⁵ At the same time, there are areas where the demands of safety and those of security conflict—creating a need for careful attention and in-depth analysis of the interface between safety and security.⁶

Unfortunately, as with weapons-usable nuclear materials, there are nuclear reactors in a number of countries that do not have effective protection against the full spectrum of plausible outsider and insider threats. Some countries see no need for on-site armed guards; yet in US security tests, the time between when an attack is first detected and when the adversaries reach areas from which they could carry out a devastating sabotage can be as little as three minutes, leaving too little time for off-site response forces to respond effectively.

States should act to fix these vulnerabilities. At a minimum, all nuclear power plants and other nuclear facilities whose sabotage could cause a major catastrophe should be protected against sabotage by a well-placed insider; a modest group of well-armed and well-trained outsiders, capable of operating as more than one team; and both an insider and outsiders working together. Plants in countries facing especially capable terrorist or criminal threats should be defended against even more capable adversaries. And all nuclear power plants should have fully operable and survivable equipment to provide emergency power and water in the event of a major accident or sabotage.

⁵ See, for example, David Lochbaum and Edwin Lyman, *U.S. Nuclear Power Safety One Year After Fukushima* (Washington, D.C.: Union of Concerned Scientists, 2012), http://www.ucsusa.org/assets/documents/nuclear_power/fukushima-anniversary-report-3-5-12.pdf (accessed March 8, 2014), p. 10.

⁶ International Nuclear Safety Group, *The Interface Between Safety and Security at Nuclear Power Plants*, IN-SAG-24 (Vienna: IAEA, 2010), http://www-pub.iaea.org/MTCD/publications/PDF/Pub1472_web.pdf (accessed March 8, 2014).

predecessors had implemented security upgrades to better protect the research reactors and their fuel.⁹² Within the United States, a substantial reduction in the number of locations with civilian HEU occurred long before the four-year effort, but little further reduction has taken place since April 2009. Within Russia, the Material Consolidation and Conversion (MCC) program has helped blend down some 16 tons of HEU; with the exception of the Krylov Shipbuilding Institute, Russia does not provide data on buildings or material balance areas cleaned out as a result of this effort, but Russian experts have indicated that they only get permission to ship HEU for blending when they have confirmed that an area will be cleaned of material requiring the highest level of security.⁹³

⁹² Data provided by NNSA officials, December 2013.

⁹³ Interview with NNSA official, January 2014.

- Substantial quantities of HEU are being removed from potentially vulnerable sites and destroyed. By the end of 2013, GTRI and its predecessors had helped remove, or confirmed secure disposition of, some 5,113 kilograms of HEU or plutonium, nearly 60 percent of which (2,990 kilograms) was removed during the four-year effort.⁹⁴ The total of over five tons substantially exceeded the goal GTRI had set, of removing or confirming the disposition of 4,353 kilograms of HEU or plutonium. The total of over five tons, however, includes 1,240 kilograms of HEU in the United Kingdom that was not included in the original target and that GTRI confirmed had been downblended over previous decades—probably entirely before the four-year effort began, and without any help from GTRI.⁹⁵ Hence, the actual amount of material GTRI contributed to removing or eliminating during the four-year effort was closer to 1,750 kilograms, leaving a good deal of the material included in the original target unaddressed—largely because GTRI did not manage to gain agreement to eliminate the HEU in Belarus and South Africa, as it had originally hoped.
- HEU-fueled reactors are being converted or shut down. Since 1978, the US government has been working with other countries to convert research reactors to use low-enriched uranium (LEU) fuel not suitable for nuclear weapons. Since then, GTRI and its predecessors have helped convert or confirmed the shutdown of some 87 HEU-fueled reactors (65 conversions and 22 shut downs); well over 100 additional HEU-fueled research reactors have shut down without any help from the US government.⁹⁶ GTRI has succeeded in accelerating the pace of these conversions and shutdowns, particularly during the four-year effort. From 1978 to the end of fiscal 2003, when GTRI was launched, its predecessor programs helped convert to LEU fuel or verify the shut-down of 39 reactors—1.5 reactors per year, on average.⁹⁷ Over the next five years, through end of fiscal 2008, GTRI converted or confirmed the shut down of 23 additional reactors, an average of 4.6 reactors per year.⁹⁸ During the next five years (including the four years of the four-year effort), GTRI converted or confirmed the shut-down of another 25 reactors or isotope production facilities (24 of which were accomplished during the four-year effort)—five reactors a year, on average.⁹⁹ Of these, however, 16 were

⁹⁴ See US Department of Energy, *The Four-Year Effort*; supplemented with data provided by NNSA, December 2013. Only about 10 kilograms of the material removed was plutonium, all of it moved during the four-year effort.

⁹⁵ According to the website Performance.gov, “1,353 kilograms of US-origin HEU...has been down-blended already and is no longer considered proliferation-attractive material. [This included the British material and some HEU elsewhere.] As a result of this confirmation, GTRI has exceeded the FY 2013 target of 3,835 kilograms of nuclear material removed or confirmed disposed. This also exceeds the goal of removing or confirming disposition of 4,353 kilograms (kg) of vulnerable nuclear material (HEU and plutonium) set for completion by December 2013 under the President’s Four Year Effort.” More detail on how the federal government evaluated their goal can be seen here: http://goals.performance.gov/goal_detail/doe/423/print (accessed March 9, 2014).

⁹⁶ Data on the 87 conversions or shutdowns provided by NNSA, March 2014. For the other shutdowns, see Ole Reistad and Strykaar Hustveit, “Appendix II: Operational, Shut Down, and Converted HEU-Fueled Research Reactors,” *Nonproliferation Review*, Vol. 15, No. 2 (July 2008), http://cns.mii.edu/npr/pdfs/152_reistad_appendix2.pdf (accessed March 8, 2014). We are grateful to Strykaar Hustveit and Frank von Hippel for data on these topics.

⁹⁷ US Department of Energy, *FY 2007 Congressional Budget Request: National Nuclear Security Administration-Defense Nuclear Nonproliferation* Vol. 1, DOE/CF-002 (Washington, D.C.: DOE, February 6, 2006), <http://energy.gov/sites/prod/files/FY07Volume1.pdf> (accessed March 11, 2014), p. 562.

⁹⁸ US Department of Energy, *FY 2011 Congressional Budget Request: National Nuclear Security Administration*, DOE/CF-0047 (Washington, D.C.: DOE, February, 2010), <http://energy.gov/sites/prod/files/FY11Volume1.pdf> (accessed March 11, 2014), p. 439.

⁹⁹ Data provided by NNSA, March 2014.

cases where GTRI confirmed that facilities were shut down (often without GTRI's help), rather than GTRI providing assistance with the conversion. If only the nine conversions were counted, this would be 1.8 reactors per year. GTRI's maximum capacity for assisting with conversions of reactors is likely in the range of five–six reactors per year, given limits on personnel with conversion expertise and the need to negotiate conversions with host countries. The 87 research reactors on GTRI's list include nine Russian HEU-fueled research reactors that have been shut down; feasibility studies for converting six Russian research reactors from HEU fuel to LEU were completed during the four-year effort, and conversion of one of these is slated for completion in 2014.¹⁰⁰ To provide incentives for reactors to convert, the United States will only export HEU for research reactor fuel to facilities that cannot use existing LEU fuels and agree to convert when appropriate fuels become available—and will take back spent fuel from reactors that agree to convert to LEU. Unfortunately, while Russia pledged at the 2012 summit “to export only LEU fuel for research nuclear reactors,” it has agreed to export HEU for a research reactor in France and a fast reactor in China, and has recently changed its export rules to make future exports of HEU easier.¹⁰¹

- HEU-based medical isotope production is being converted. When the four-year effort began, more than 95 percent of the world's production of the most important medical isotope—molybdenum-99 (known as moly-99) was made using HEU—often weapon-grade, and usually irradiated for so short a time that the “waste” from this production remained very highly enriched and only lightly radioactive. The four-year effort saw substantial progress in converting this production. First, South Africa became the first of the major suppliers to begin producing medical isotopes with LEU.¹⁰² Second, Belgium and the Netherlands, two of the other major suppliers, committed to convert to production without the use of HEU by 2015 (though it is not clear in the Dutch case whether this target will be met).¹⁰³ Third, Canada, the other major traditional supplier, expects to end its HEU-based

¹⁰⁰ NNSA, “US, Russian Federation Sign Joint Statement on Reactor Conversion” (Washington, D.C.: NNSA, June 26, 2012), <http://www.nnsa.energy.gov/mediaroom/pressreleases/jointstatement062612> (accessed March 8, 2014).

¹⁰¹ See, for example, “Russia to Supply HEU to Research Reactors Abroad,” blog of the International Panel on Fissile Materials, January 30, 2014, http://fissilematerials.org/blog/2014/01/russia_to_supply_heu.html (accessed March 8, 2014). For the 2012 Russian statement, see Office of the President of Russia, “Memorandum of the Russian Federation for the 2012 Nuclear Security Summit” (Moscow: Office of the President of Russia, March 27, 2012), http://eng.news.kremlin.ru/ref_notes/80 (accessed March 8, 2014).

¹⁰² Because of constraints on approvals for isotopes produced by the new process, however, South Africa has not yet fully converted to non-HEU production. Smaller suppliers, such as Australia and Argentina, had already been producing medical isotopes without HEU, and in 2012, Australia announced it was expanding production. For information on South Africa, see Parrish Staples, NNSA, “Testimony before the Senate Committee on Energy & Natural Resources,” February 1, 2011. <http://nnsa.energy.gov/mediaroom/congressionaltestimony/staplestestimony2111>, (accessed February 24, 2014).

¹⁰³ For the European commitment, see The White House, Office of the Press Secretary, “Belgium-France-Netherlands-United States Joint Statement: Minimization of HEU and the Reliable Supply of Medical Radioisotopes” (Washington, D.C.: The White House, March 26, 2012), <http://www.whitehouse.gov/the-press-office/2012/03/26/belgium-france-netherlands-united-states-joint-statement-minimization-he> (accessed March 8, 2014). For an indication that technical difficulties may delay conversion in the Netherlands, see Parrish Staples, “Ensuring Reliable Supplies of Molybdenum-99 Produced Without Highly Enriched Uranium,” presentation to the 35th Annual High Country Nuclear Medicine Conference, Vail, Colorado, March 3, 2014, <http://www.hcnmc.org/wp-content/uploads/2014/03/Staples.pdf> (accessed March 8, 2014). (The authors are grateful to Alan Kuperman for providing this

production in 2016, when the aging reactor used for this purpose closes.¹⁰⁴ Fourth, Russia is moving toward large-scale production for the international market with both HEU reactor fuel and HEU targets, but has committed to convert its targets to LEU by 2016.¹⁰⁵ Fifth, the US Congress passed the American Medical Isotope Production Act (AMIPA) of 2012, which established a cutoff of US HEU exports for isotope production after seven years (with the possibility of an extension if a shortage arose), and provided funding to support development of non-HEU sources of medical isotopes.¹⁰⁶ Sixth, based on AMIPA, GTRI has funded R&D on several options for domestic US production of medical isotopes without HEU.¹⁰⁷ Moreover, in early 2013, the Medicaid and Medicare programs began providing a \$10 premium for medical procedures using isotopes produced without HEU; over time, other markets may also preferentially purchase non-HEU isotopes, effectively driving HEU production out of the market.¹⁰⁸ By the end of FY 2019, GTRI hopes to have helped convert all large-scale medical isotope production away from the use of HEU targets.¹⁰⁹

GTRI's programs to consolidate HEU did not end at the end of the four-year effort. By December 2016, GTRI hopes to work with other countries to remove or dispose of an additional 1,100 kilograms of fresh or spent HEU and help eight additional countries eliminate their HEU stocks entirely. GTRI has also identified more than 400 kilograms of plutonium at research facilities that could be disposed of or returned to its country of origin.¹¹⁰ By the end of 2019, GTRI hopes to convert or confirm the shutdown of an additional 36 HEU-fueled reactors, bringing the cumulative total to 124 HEU-fueled research reactors, out of its target of 200 by 2030.¹¹¹

Civilian Plutonium

In contrast to civilian HEU, there has been only minor progress in consolidating civilian plutonium—and there are disturbing trends in the opposite direction. GTRI has helped a small number of countries eliminate a few small stocks of plutonium, including cleaning the last weapons-usable nuclear material out of Sweden, announced at the Seoul nuclear security summit in March

reference.)

¹⁰⁴ See Ian Macleod, "Ottawa Vows to Make Uranium-Free Isotopes," *Calgary Herald*, March 1, 2013, <http://www2.canada.com/calgaryherald/news/story.html?id=dcbl1a75-6a29-42b8-9e5c-e5c23dd161ed&p=1> (accessed February 24, 2014). See also Staples, "Ensuring Reliable Supplies."

¹⁰⁵ *Civilian HEU Reduction and Elimination Resource Collection: Why Is Highly Enriched Uranium a Threat?* (Washington, D.C.: Nuclear Threat Initiative, 8 January, 2014), <http://www.nti.org/analysis/reports/civilian-heu-reduction-and-elimination/> (accessed on February 24, 2014).

¹⁰⁶ For a description of AMIPA, see Staples, "Ensuring Reliable Supplies." In part, AMIPA was correcting previous legislation that had gutted earlier restraints on US HEU exports for isotope production. For a pointed critique of the lobbying that led to that earlier change, see Alan J. Kuperman, "Bomb-Grade Bazaar: How Industry, Lobbyists, and Congress Weakened Export Controls on Highly Enriched Uranium," *Bulletin of the Atomic Scientists*, March/April 2006, pp. 44–50.

¹⁰⁷ For a discussion of HEU in medical isotope production generally and Russian production in particular, see Anton Khlopkov and Miles Pomper with Valeriya Chekina, "Ending HEU in Medical Isotope Production: Options for U.S.-Russia Cooperation" (Washington, D.C.: Nuclear Threat Initiative, February 14, 2014), http://www.nti.org/media/pdfs/Ending_HEU_Use_in_Medical_Isotope_Production.pdf (accessed March 8, 2014). The 2016 target date for conversion of targets was provided by NNSA officials, March 2014.

¹⁰⁸ See Staples, "Ensuring Reliable Supplies."

¹⁰⁹ Data provided by NNSA officials, December 2013.

¹¹⁰ Data provided by NNSA officials, December 2013.

¹¹¹ Data provided by NNSA officials, December 2013.

2012.¹¹² GTRI plans some larger plutonium removals in the next few years; as noted earlier, for example, press accounts suggest that at the nuclear security summit in The Hague in March 2014, Japan will announce that it is eliminating hundreds of kilograms of plutonium from its Fast Critical Assembly at Tokai. It seems quite plausible that GTRI will succeed in eliminating all the small, unneeded stocks of plutonium that exist in the world in the next few years.

But plutonium continues to be separated on a massive scale and, in some countries, the number of sites and transports with separated plutonium appears likely to expand. Civilian stocks of separated plutonium have built up as reprocessing outpaced the use of the resulting plutonium as fuel. Today, there is as much civilian separated plutonium as there is in all the world's stocks of nuclear weapons.¹¹³ The US plan for using its excess weapons plutonium as reactor fuel appears to have collapsed in the midst of massive cost overruns (though the United States says it remains committed to some form of long-term disposition once studies of alternatives are completed); the U.K. says it also plans to use its stockpile of over 100 tons of excess civilian separated plutonium as fuel, but has no reactors licensed and willing to use it and no working plant to fabricate the fuel; Japan, despite the Fukushima accident, appears determined to bring the huge reprocessing plant at Rokkasho-mura into full operation, with the potential for separating a thousand bombs' worth of plutonium every year, despite a commitment not to accumulate separated plutonium and strong public opposition to using plutonium fuel in Japanese reactors; Russia is about to complete the BN-800 fast neutron reactor, slated to use fuel made from excess weapons plutonium, but has far more separated plutonium than the BN-800 and the old BN-600 could possibly use in their lifetimes, and continues to separate more; and, even in France, which has the most successful plutonium recycling program, over 80 tons of separated plutonium have built up in storage, the reactors licensed to use plutonium are aging, and the utility and the reprocessing company are arguing fiercely over the costs of continuing.¹¹⁴ China, meanwhile, is considering buying a reprocessing plant from France and two fast-neutron plutonium breeder reactors from Russia, while South Korea is seeking prior consent to use US-origin materials in "pyroprocessing"—a reprocessing technique that does not fully separate the plutonium, but still poses serious proliferation risks—to manage its spent nuclear fuel.

Overall, however, because reprocessing spent fuel is far more expensive than storing it, fewer and fewer utilities are willing to contract for reprocessing; outside of Japan, India, and possibly China in the future, the scale of reprocessing plutonium looks likely to decline. The UK reprocessing program bankrupted British Nuclear Fuels Ltd, and the UK reprocessing plant is expected to close when it completes its existing contracts; the aging Russian reprocessing plant at Mayak is operating at roughly a quarter of its capacity, for lack of contracts; and the French re-

¹¹² The White House, Office of the Press Secretary, "Fact Sheet: Plutonium Removal From Sweden" (Washington, D.C.: The White House, March 26, 2012), <http://www.whitehouse.gov/the-press-office/2012/03/26/fact-sheet-plutonium-removal-sweden> (accessed March 8, 2014).

¹¹³ International Panel on Fissile Materials, *Global Fissile Materials Report 2013*, pp. 18–23.

¹¹⁴ See *Global Fissile Material Report 2013: Increasing Transparency of Nuclear Warhead and Fissile Material Stocks as a Step toward Disarmament*, (Princeton, New Jersey: Seventh annual report of the International Panel on Fissile Material, October 2013), <http://fissilematerials.org/library/gfmr13.pdf> (accessed February 24, 2014); "Rokkasho reprocessing plant expects to begin operations in October 2014," International Panel on Fissile Material Blog, January 7, 2014, http://fissilematerials.org/blog/2014/01/rokkasho_reprocessing_pla_1.html (accessed March 8, 2014); "BN-800 fast reactor to reach criticality in April 2014," International Panel on Fissile Material Blog, December 26, 2013, http://fissilematerials.org/blog/2013/12/bn-800_fast_reactor_to_re.html (accessed February 24, 2014).

processing facilities are operating at roughly half their capacity, again for lack of contracts to do more.¹¹⁵ Nevertheless, as countries struggle to cope with the plutonium building up from ongoing reprocessing, the number of plutonium transports remains high and the number of sites using separated plutonium may well increase, creating additional risks that must be managed through stringent nuclear security and accounting measures.

Military Stockpiles

There has been some progress in consolidating military stockpiles, particularly in the United States. As noted earlier, the United States and Russia have greatly reduced the number of sites where their nuclear weapons are stored (though nearly all of that consolidation was associated with winding down the Cold War and occurred before the four-year effort began).

In the United States, the cost of meeting post-9/11 security regulations has motivated DOE and its facility managers to eliminate HEU and separated plutonium from as many sites and buildings as possible. In September 2012, for example, the United States completed removing all kilogram quantities of plutonium and HEU from Lawrence Livermore National Laboratory; Sandia National Laboratory had already been cleaned out, so two out of the three US nuclear weapons laboratories no longer regularly hold substantial quantities of weapons-usable nuclear material.¹¹⁶ DOE expects to save \$40 million per year in security and safety costs as a result of removing this material from Livermore. All told, the removal of weapons-usable nuclear material from entire sites (such as Rocky Flats), from major facilities (such as Technical Area 18 at Los Alamos), and from dozens of buildings at other sites is saving DOE hundreds of millions of dollars a year in security costs—though the costs of meeting post-9/11 security rules remain well over a billion dollars a year.¹¹⁷ All but one of the US HEU-fueled critical assemblies—facilities that often

¹¹⁵ For an account of the British reprocessing program, see Martin Forwood, *The Legacy of Reprocessing in the United Kingdom*, International Panel on Fissile Material Research Report #5, (International Panel on Fissile Materials, July 2008), <http://fissilematerials.org/library/rr05.pdf> (accessed March 8, 2014), p. 36. For information on Mayak reprocessing, see International Panel on Fissile Materials, “Countries: Russia,” Last modified March 11, 2013, <http://fissilematerials.org/countries/russia.html> (accessed March 8, 2014). For information on reprocessing in France, see Mycle Schneider and Yves Marignac, *Spent Nuclear Fuel Reprocessing in France*, International Panel on Fissile Material Research Report #4, (Princeton, New Jersey: International Panel on Fissile Materials, May 2008), <http://fissilematerials.org/library/rr04.pdf> (accessed March 8, 2014).

¹¹⁶ NNSA, “NNSA Completes Removal of All High Security Special Nuclear Material From LLNL” (Washington, D.C.: NNSA, September 21, 2012), <http://nnsa.energy.gov/mediaroom/pressreleases/snmremoval092112> (accessed March 8, 2014). NNSA eliminated all the “Category I” and “Category II” material from Livermore—the highest security categories. Livermore still handles “Category III” quantities of HEU and separated plutonium (less than 400 grams of pure plutonium or less than one kilogram of U-235 in HEU, or, under DOE rules, somewhat larger amounts of compounds containing these materials); on occasion, larger amounts may be used at Livermore temporarily. Sandia still operates the Annual Core Research Reactor, which uses 35 percent enriched HEU. Under international standards, this material would be considered Category II, because there is a quantity large enough to be Category I, but the material in the reactor core is radioactive enough that its category can be reduced one level. But under DOE rules, material that is less than 10 percent by weight U-235 or plutonium is considered in a lower attractiveness category. See discussion in US Department of Energy, Office of the Inspector General, *Inspection Report: Removal of Categories I and II Special Nuclear Material From Sandia National Laboratories-New Mexico*, DOE/IG-0833 (Washington, D.C.: January 2010).

¹¹⁷ US Department of Energy, *FY 2014 Congressional Budget Request: Other Defense Activities, Departmental Administration, Inspector General, Working Capital Fund, Safeguards and Security Crosscut, Pensions*, DOE/CF-0085 Vol. 2 (Washington, D.C.: DOE, April 2013), <http://energy.gov/sites/prod/files/2013/04/f0/Volume2.pdf>, (accessed

have tens or hundreds of kilograms of high-quality HEU at a single site—are now located at the Device Assembly Facility (DAF) in Nevada, thought to be one of the most secure facilities in the US nuclear complex.¹¹⁸

In Russia, there was some significant consolidation of the military nuclear complex in the two decades following the collapse of the Soviet Union—including the shut-down of all the remaining plutonium production reactors (with US assistance), the end of weapons component fabrication at the Siberian Chemical Combine in Seversk (concentrating the remaining work at the Mayak Production Association in Ozersk) and the closure of two of Russia’s four nuclear weapons assembly and disassembly facilities.¹¹⁹ More recently, Russia has announced that HEU fuel fabrication for the Russian Navy will be concentrated at the Elektrostal Machine-Building Plant, eliminating HEU from the Novosibirsk Chemical Concentrates Plant.¹²⁰ But Russia continues to have over 200 buildings with HEU or separated plutonium—many of them in the ten closed nuclear cities of the nuclear weapons complex—and scores of sites where nuclear weapons are stored.¹²¹ This is a far larger complex of nuclear weapons, HEU, and plutonium sites than any other nuclear weapons state finds necessary, and creates significant costs and risks.

Pakistan, as noted earlier, is expanding its nuclear arsenal more rapidly than any other country, with a fourth plutonium production reactor coming on-line soon. As Pakistan shifts toward tactical nuclear weapons, it appears that not only the number of weapons, but the number of sites will expand as well - and that nuclear weapons will be dispersed to still more locations early in any future nuclear crisis. Moreover, these weapons will be smaller and more mobile, making theft easier.

Other states with military nuclear stockpiles generally have modest stockpiles in modest numbers of locations, which are not changing very rapidly. France and the United Kingdom, however, have reduced their stockpiles and the number of locations for them over the last twenty years. China, like France and the United Kingdom, has a modest stockpile in only a few locations, but China has maintained greater secrecy about the specifics.

March 8, 2014) pp. SS-1-SS-11.

¹¹⁸ These critical assemblies were moved from Technical Area 18 at Los Alamos—which was down in a valley, vulnerable to attack from above, and as DOE concluded, simply could not be defended effectively at reasonable cost—and from Livermore. The remaining HEU-fueled critical assembly not at the DAF is at Idaho National Laboratory. For a list, see International Panel on Fissile Materials, “Research and Isotope Production Reactors,” last updated October 25, 2013, http://fissilematerials.org/facilities/research_and_isotope_production_reactors.html (accessed March 8, 2014).

¹¹⁹ See discussion in Pavel Podvig, *Consolidating Fissile Materials in Russia’s Nuclear Complex* (Princeton, N.J.: International Panel on Fissile Materials, Program on Science and Global Security, and Princeton University, May, 2009), <http://fissilematerials.org/library/rr07.pdf> (accessed March 11, 2014).

¹²⁰ Pavel Podvig, “Russia to Consolidate HEU Fuel Production in Electrostal,” blog of the International Panel on Fissile Materials, June 4, 2012, http://fissilematerials.org/blog/2012/06/russia_to_consolidate_heu.html (accessed March 8, 2014). More recently, some at Novosibirsk have suggested that this decision will be reconsidered and the facility will continue to process HEU. Pavel Podvig, personal communication, March 2014.

¹²¹ As noted earlier, Russia and the United States have completed security upgrades at 218 buildings holding HEU or separated plutonium, and plan to complete such upgrades at 11 more. An unknown number of additional buildings with these materials, probably in the range of a couple of dozen, have not been subject to US-Russian cooperation, particularly at Russia’s two remaining nuclear weapons assembly-disassembly facilities.

Remaining Consolidation Gaps

In each of the categories just discussed—civilian HEU, civilian plutonium, and military stockpiles—there is much more to be done to reduce the number of sites with these items and materials to the minimum necessary to fulfill ongoing civilian and military requirements. Despite the successes of the efforts to convert or shut down HEU-fueled research reactors, around the world there are over 120 research, training, or isotope production reactors that still use HEU fuel or targets.¹²² Current plans for converting HEU-fueled research reactors are scheduled to be completed in 2030—17 years after the end of the four-year effort, and five years later than was planned at the time of our last report two years ago.¹²³ Sites handling civilian plutonium appear likely to expand, rather than contract—and there are no focused US or international efforts to address this problem (beyond GTRI’s effort to recover a few small stockpiles). The number of locations where military stocks are located remains far larger than needed, with no US or international efforts focused on reducing it. Existing consolidation efforts face major challenges in meeting the targets they have set, but do not yet cover all the types of materials and facilities for which consolidation should be considered, or all the policy approaches and incentives that might be effective.¹²⁴

Russia’s outsized complex. Russia poses the largest challenges. Russia has almost as many HEU-fueled research, training, or isotope production reactors as the rest of the world combined.¹²⁵

In particular, almost two thirds of the world’s HEU-fueled critical assemblies and pulse reactors are in Russia. These are particularly dangerous types of research reactors, often having hundreds of kilograms or even tons of high-quality HEU (and in some cases, high-quality plutonium as well) at a single site, with fuel that is hardly radioactive at all because so little actual fission takes place in these facilities. For the same reason, their fuel lasts indefinitely and does not need to be replaced, giving these facilities little incentive to switch to low-enriched fuel unless governments require them to do so or create incentives to do so (for example, by imposing security rules that result in high costs for guarding such stocks of HEU and plutonium, as in the US case). Many of these pulse reactors and critical assemblies still exist more because of institutional inertia than research needs. Similarly, as noted earlier, Russia has far more nuclear weapon storage locations and weapons-usable nuclear material buildings than any other country.

HEU and HEU-fueled research reactors. Tens of tons of civil HEU still exist around the world—far more than the roughly five tons GTRI has managed to address so far. While most of the world’s civil HEU is in the United States or Russia, many tons still exist in other countries as well.¹²⁶ GTRI recently completed a study of the 26.1 tons of HEU the United States exported over the years, and found that approximately 15 tons had either been returned to the United States or blended down—leaving roughly 11 tons either still located in foreign countries, or with its fate still unresolved.¹²⁷

¹²² International Panel on Fissile Material, “Facilities: Research and Production Targets.”

¹²³ Fissile Materials Working Group, “US budget cuts threaten nuclear safety,” *Bulletin of Atomic Scientists*, May 28, 2013, <http://thebulletin.org/us-budget-cuts-threaten-nuclear-safety> (accessed February 14, 2014).

¹²⁴ Bunn and Harrell, *Consolidation*.

¹²⁵ International Panel on Fissile Material, “Facilities: Research and Production Targets.”

¹²⁶ International Panel on Fissile Material, *Global Fissile Materials Report 2013*, pp. 10–15.

¹²⁷ Data provided by NNSA officials, December 2013. The fate of roughly 1.3 tons of US-origin HEU remained unresolved at that time; additional discussions with officials in France and elsewhere are now expected to clarify what became of that material.

This study was an important step because, prior to the study's completion, the United States had little understanding of where the nuclear material it had given to other countries was stored.¹²⁸ GTRI is now considering expanding its HEU disposition and return efforts to cover just under half of this material (5.3 tons).¹²⁹ That effort, even if successful, would leave tons of US-origin HEU around the world (largely in irradiated form). The current plan not to return substantial portions of this HEU results in part from these materials being in forms no US facility is currently equipped to handle, and in part because some countries have no interest in giving up stocks of HEU for facilities they still consider useful.¹³⁰ Some countries, notably Belarus and South Africa, have so far not agreed to ship out or blend down their HEU.

As noted earlier, some 123 research, training, or isotope production reactors still use HEU as their fuel. GTRI hopes to address most of these, but faces many challenges in doing so. Many of these facilities are in Russia, and while there has been close US-Russian cooperation focused on six of Russia's research reactors (and Russia has recently agreed to pursue feasibility studies for conversion of two more), there has been no sustained dialogue about the broader problem of dozens of HEU-fueled reactors in Russia. In addition, there are still some 27 steady-state HEU-fueled reactors, using over 500 kilograms of HEU as fuel every year, that can only convert if new, higher-density fuels are developed—and development of those fuels has repeatedly encountered major delays.¹³¹ Those delays, combined with projected budget constraints, are major reasons why GTRI does not expect to complete its reactor conversion effort until 2030. Even beyond Russia, convincing reactor operators to convert will remain a difficult task—especially for those facilities, such as low-power reactors, critical assemblies, and pulse reactors, that have no need for new fuel.

Plutonium and military stockpiles. As noted earlier, while GTRI has begun to remove small stocks of unneeded plutonium from a small number of countries—and hopes to help countries eliminate another 400 kilograms of plutonium in the future—there are no US or international programs focused on limiting the massive growth of civilian plutonium stockpiles or the number of civilian sites where such large-scale use will take place in the future. Moreover, at present there are no US or international programs focused on reducing the number of military sites with nuclear weapons, HEU, or separated plutonium.

¹²⁸ US Congress, Government Accountability Office, *U.S. Agencies Have Limited Ability to Account for, Monitor, and Evaluate the Security of U.S. Nuclear Material Overseas*, GAO-11-920 (Washington, D.C.: GAO, September 2011), <http://www.gao.gov/assets/330/323048.html> (accessed March 8, 2014).

¹²⁹ Data provided by NNSA officials, December 2013.

¹³⁰ Note, however, that much of the HEU not covered by DOE's expanded approach is in forms that are less attractive for use in weapons, either because they are highly radioactive, or because they are at enrichments much less than weapons grade, or they are in chemical forms that might make separation somewhat difficult.

¹³¹ US Department of Energy, *FY 2013 Congressional Budget Request: National Nuclear Security Administration*, Vol. 1, DOE/CF-0071 (Washington, D.C.: DOE, February, 2012), <http://energy.gov/sites/prod/files/FY13Volume1.pdf> (accessed March 11, 2014), p. 468.

Security for Radioactive Sources

In countries all over the world, hundreds of thousands of radiological sources are providing a wide range of benefits to society, from cancer treatment to finding flaws in welds. These sources range from tiny bits of radioactivity in smoke detectors to powerful sources of deadly gamma rays—used, for example, to irradiate tumors. While only a couple of dozen countries have nuclear weapons or weapons-usable nuclear materials, and only 31 countries operate nuclear power plants, radioactive sources that terrorists could use to make a radioactive “dirty bomb” are widespread. By one estimate, radiological sources big enough to pose a serious danger exist in over 13,000 buildings in over 100 countries.¹

The consequences of a “dirty bomb” attack would be dramatically smaller than those of a nuclear bomb. A dirty bomb would simply contaminate an area—it would not kill tens or hundreds of thousands of people as a nuclear bomb would. Indeed, in most scenarios, a dirty bomb would produce few radiation fatalities, but the need to evacuate and clean up many blocks of a city could cause considerable disruption and economic damage.² And getting and using the material for a dirty bomb would be far easier than getting HEU or plutonium and making a crude nuclear bomb from it.

The December 2013 truck-jacking in Mexico, in which thieves stole a truck with an extremely dangerous 3,000-curie source—and someone later removed the source from its shielding—highlighted the continuing dangers posed by insecure radioactive sources. The reality is that both in use and during transport, many radioactive sources around the world are dangerously insecure.³

Given the huge numbers of radioactive sources in use, it is hopeless to try to provide highly effective security for all of them. Instead, global radiological security efforts have focused primarily on the largest radioactive sources that could contaminate substantial areas if used as a dirty bomb—mainly the ones designated by the IAEA as “Category I” or “Category II” sources.⁴

Every country using such sources should:⁵

- Require operators to provide appropriate security measures – including alarms that would notify police or other response forces if the source were removed or tampered with; appropriate locks and equipment designs to increase the time and effort required to remove a source (such as making it impossible to remove without explosives or special tools); and armed personnel where appropriate.⁶

¹ Estimate provided by NNSA, July 2013.

² See, for example, JiYoung Park, “The Economic Impacts of Dirty Bomb Attacks on the Los Angeles and Long Beach Ports: Applying the Supply-Driven NIEMO (National Interstate Economic Model),” *Journal of Homeland Security and Emergency Management*, Vol. 5, No. 1, 2008, <http://www.degruyter.com/view/j/jhsem> (accessed March 8, 2014).

³ For a useful account of the incident in Mexico and next steps in securing radiological sources around the world, see Tom Bielefeld, “Mexico’s Stolen Radiation Source: It Could Happen Here,” *Bulletin of the Atomic Scientists*, January 23, 2014, <http://thebulletin.org/mexico%E2%80%99s-stolen-radiation-source-it-could-happen-here> (accessed March 8, 2014).

⁴ For a description of which sources fall in which category, see International Atomic Energy Agency, “Code of Conduct on the Safety and Security of Radioactive Sources” (Vienna: IAEA, 2004).

⁵ See Matthew Bunn and Tom Bielefeld, “Reducing Nuclear and Radiological Terrorism Threats,” in *Proceedings of the Institute for Nuclear Materials Management 48th Annual Meeting*, Tucson, Arizona, July 8-12, 2007 (Northbrook, IL: INMM, 2007).

⁶ For example, NNSA’s Global Threat Reduction Initiative has worked with manufacturers to create new designs that make it far more difficult for adversaries to remove radioactive sources from machines that use them, and kits to modify machines already in use. Such “in-device delay” technology had been installed on more than 200 cesium chloride irradiators (some of the most dangerous sources in use) in the United States by April 2013. See National Nuclear Security Administration, “NNSA: Securing Domestic Radioactive Material” (Washington, D.C.: NNSA, April 12, 2013), <http://nnsa.energy.gov/mediaroom/factsheets/gtri-protect> (accessed March 9, 2014).

Security for Radioactive Sources (cont.)

- Provide training programs to inform operators of the best ways to secure sources—and to highlight the ongoing danger these sources pose.
- Require transporters to provide appropriate security measures, including continuous tracking of vehicles carrying such sources, use of genuinely safe “safe havens” when drivers are sleeping or stopping, armed escorts where appropriate, a “panic button” allowing drivers to signal if trouble comes up, and engineered vehicle features that would make the vehicle and its contents more difficult to steal (as armored cars for transporting valuables routinely have—such as a button that effectively stops the vehicle from being driven). This should include improved security training for all drivers of dangerous radioactive sources.
- Maintain a cradle-to-grave register tracking the location and use of each source.
- Provide safe and secure options for disposing of such sources when they are no longer needed, with requirements for users to send them there.
- Establish a program for finding and securing lost and orphan sources, potentially including through effective use of radiation detection equipment.
- Shift quickly to non-radioactive alternatives wherever practicable – such as the linear accelerators now used in the United States and other developed countries instead of the type of teletherapy source stolen in the incident in Mexico.

In addition, because a great deal of the impact of a radiological dirty bomb would come from the public fear of radiation, it is crucial to begin preparing public communication strategies and broader emergency response and cleanup approaches to mitigate the disruption and fear that might result as much as practicable.

The United States, the IAEA, and other donors have been helping countries take such steps, and have made significant progress, removing thousands of unneeded sources around the world and installing security upgrades for sources in some 1,500 buildings, within the United States and elsewhere – including both the hospital the Mexican source was being transported from and the storage site to which it was headed.⁷ For example, Russia, the United States, and other countries are cooperating to replace all of Russia’s roughly 820 radio-thermoelectric generators (RTGs)—each with tens of thousands of curies of material—by the end of 2016; over 800 have already been eliminated.⁸ Unfortunately, in fiscal year 2013, in the midst of the four-year effort, the Obama administration sharply reduced the budgets for these radiological security efforts, stretching the program out to 2044.⁹ It seems clear that if there is a threat worth spending US taxpayer dollars to address, it is worth addressing the threat before 30 years in the future.

In short, there is a great deal still to be done to provide effective security for radiological sources. States should take action to secure and track their own sources, and lean on others to do likewise—and the United States should restore the budget for its effort to assist, with the goal of getting the job done in far less than thirty years.

⁷ NNSA, “NNSA: Securing Domestic Radioactive Material.” Information on Mexican upgrades provided by NNSA officials, January 2014.

⁸ See US National Nuclear Security Administration, “GTRI: Removing Vulnerable Civilian Nuclear and Radiological Material” (Washington, D.C.: NNSA, October 31, 2013), <http://nnsa.energy.gov/mediaroom/factsheets/gtri-remove> (accessed March 9, 2014).

⁹ US Department of Energy, *FY 2014 NNSA Budget Request*, pp. DN–19, DN–22.

Progress on Security Culture, Best Practices, and Training

The “human factor” in nuclear security is crucial. Modern security and accounting equipment and stringent nuclear security requirements will only provide effective security if they are backed up by people who are focused on achieving high levels of security, who implement the best available practices for doing so, and who have the knowledge they need to do their jobs, ideally with professional certification. This section discusses progress in each of these areas during the four-year effort—though progress in each of these areas is especially difficult to assess.

Security Culture

Retired Gen. Eugene Habiger, former commander of US strategic forces and former “security czar” at the US DOE, summed up the importance of an organization’s culture: “good security is 20 percent hardware and 80 percent culture.”¹³² By “culture,” Habiger meant an organization’s daily focus on nuclear security, and on constantly seeking to find and fix vulnerabilities.

As noted above, the United States and Russia have long had a working group on security culture. During the four-year effort, Rosatom directed that its major facilities each appoint security culture coordinators whose job is to promote security culture at their sites. These coordinators meet and exchange ideas regularly. (The reality is that no comparable approach exists in the United States—or in other countries, as far as the authors are aware.) The United States has also sponsored joint workshops on security culture with experts from China, the United Kingdom, and other countries.

The IAEA’s guide for strengthening security culture was published in 2008, just before the four-year effort began.¹³³ WINS published its guide, targeted especially as advice for operators, just at the beginning of the four-year effort in 2009—and included a set of questions for organizations to use to assess their own security cultures.¹³⁴ Since then, the IAEA and WINS have conducted security culture workshops in many countries, and many countries have begun exploring how to strengthen their own nuclear security cultures. Security culture is a prominent feature of the curricula of the training centers several countries are establishing (discussed below).

But how much has the culture at key facilities managing nuclear weapons or weapons-usable nuclear material actually changed? The short answer appears to be: “not as much as is needed at most places.”

The Y-12 incident and recent issues with cheating on tests and drunkenness among US intercontinental ballistic missile officers suggest that security culture remains a serious problem in the United States—despite literally decades of efforts to address the problem in response to past incidents.¹³⁵ In many other countries, belief in the threat, the key driver of a strong security culture,

¹³² Habiger, interview, October 2003.

¹³³ International Atomic Energy Agency, “Nuclear Security Culture: Implementing Guide” (Vienna: IAEA, 2008).

¹³⁴ World Institute for Nuclear Security, *Nuclear Security Culture: A WINS Best Practice Guide for Your Organization*, Rev. 1.4 (Vienna: WINS, September 2009).

¹³⁵ For an extremely harsh critique of security culture at the Department of Energy in the 1990s—with a remarkable list of studies of the problem dating back almost to the dawn of the nuclear age—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, June, 1999), <http://www.fas.org/sgp/library/pfiab/> (accessed March 8, 2014).

is even less widespread than it is in the United States. Many organizations have few incentives in place for managers or staff to spend their time on improving nuclear security. The US government has found that building and sustaining a strong nuclear security culture domestically poses a difficult problem in itself, even where the US government sets the rules, pays the costs, and hires and fires the facility leadership. Finding ways that the US government or other governments interested in strengthening security culture can effectively influence security culture in other countries, where they have only a partial understanding of the national culture and access to few of the key levers of power poses a profound policy challenge.

Inherent security culture problems pose another strong argument for minimizing the number of sites where nuclear weapons and weapons-usable material exist and for pursuing “inherently secure” systems that rely less on the human factor (massive concrete blocks piled over the channels where cans of plutonium are stored at Mayak are one example of an approach that is cheap, inherently sustainable, and requires only modest vigilance by staff). But as General Habiger observed, culture is likely to remain a critical element of an effective nuclear security system.

Best Practices

Companies often strive to become more competitive by adopting the best ideas they can find—from within the company, from other companies in their industry, and from companies in other businesses. The goal is to shift from a compliance-based culture—“do what the rules say you have to, and no more”—to a performance-based culture, constantly striving for best-in-class performance. As one industry expert remarked, “no one ever wrote a book called *Regulate Your Way to Excellence*.”¹³⁶ Effective regulation of nuclear security is crucial—but it is not sufficient.

Nuclear safety has benefited enormously from a similar conscious effort to promote the use of best practices and focus on continuous improvement. In nuclear security, this focus on identifying and promoting the adoption of best practices is only in its early stages—but has the potential to have a crucial impact.

The IAEA has an expanding collection of recommendations and technical guidance on how to implement various aspects of nuclear security.¹³⁷ Developed by experts from member states and approved by a committee open to all, these have gained considerable political legitimacy, and are used by many countries.

The efforts of WINS, the first non-government organization focused on helping operators share and implement nuclear security best practices, were especially important in promoting best practices during the four-year effort. WINS was established at the end of 2008, just before the four-year effort began, and has since produced dozens of best practice guides on topics ranging from managing guard forces to the role a company’s board of directors should play in nuclear security.¹³⁸ WINS members now number over 1,600 in nearly 100 countries. Over 86 percent of

¹³⁶ Quoted in William H. Tobey, *Defining and Implementing Best Practices in Nuclear Security* (Cambridge, Mass.: Belfer Center for Science and International Affairs, Harvard Kennedy School, 2012), http://belfercenter.ksg.harvard.edu/files/William_Tobey_Defining%20and%20Implementing.pdf (accessed March 8, 2014), p. 6.

¹³⁷ For a listing, see the website of the Nuclear Security Series publications, <http://www-ns.iaea.org/security/nss-publications.asp?s=5> (accessed March 8, 2014).

¹³⁸ All the WINS guides are available to members on its website, <http://www.wins.org>. For the present, membership is free. (One of the authors of this report, William Tobey, is chair of the board of directors of WINS).

WINS members who responded to their survey reported that they had changed security practices because of information they received from WINS.¹³⁹

In addition to WINS, the United States and Russia have carried out a substantial number of bilateral best practice workshops on topics ranging from strengthening security culture to budgeting for nuclear security. Some of these have been trilateral workshops, with experts from the U.K. participating as well. The United States has also carried out a number of bilateral best-practice workshops with other countries—particularly with China, where they are a major focus of US-Chinese nuclear security cooperation.

The IAEA's International Physical Protection Advisory Service (IPPAS) is another important mechanism for spreading best practices (and finding and correcting weak practices). The IPPAS teams review the physical protection arrangements in place at a particular site, and the state's physical protection regulations and approaches, and it identifies both good practices and elements that should be changed. As discussed in the governance section below, during the four-year effort, a much larger number of states requested IPPAS missions, making this mechanism for spreading best practices more broadly applicable. (It remains the case, however, that only a few of the sites in the world with HEU or separated plutonium, and none of those with nuclear weapons, have ever had an IPPAS mission.)

As with the efforts on nuclear security culture, it is difficult to judge how much difference these best practice efforts have made in leading to real reductions in the risk of nuclear theft. It is unfortunate that countries such as Russia, Pakistan, China—and France, somewhat surprisingly—have not been active supporters of WINS. Nevertheless, in a number of countries, including some of those just mentioned, visits to nuclear sites and discussions with nuclear experts make clear that there are real efforts underway to adopt best practices suggested by experts from other countries. The results of best practice exchanges are likely to be slow and evolutionary, as facility after facility adopts improved approaches—but they are nevertheless real.

Nuclear Security Training

Effective nuclear security requires a substantial number of people with specialized skills—from armed tactical response to fixing electronic intrusion detectors to measuring nuclear material. For decades, the US DOE has operated a National Training Center offering a broad range of instruction in nuclear security and accounting.¹⁴⁰ A number of other countries have had similar training programs, and since 1978, Sandia National Laboratories has offered an international training course in physical protection under IAEA auspices every 18 months. In the 1990s and 2000s, the United States helped Russia establish a number of important nuclear security training centers, along with a center in Ukraine.¹⁴¹ But the reality has been that most nuclear security staff learned

¹³⁹ Over 97 percent agreed that attending a WINS workshop was time well spent, and over 91% agreed that the guides WINS publishes provide effective tools for organizations to assess their own security performance in the area covered by the guide. World Institute for Nuclear Security, *Reaching New Heights: Annual Report 2013* (Vienna: WINS, 2013), p. 17.

¹⁴⁰ The center's course catalog is at its website, <https://ntc.doe.gov/>.

¹⁴¹ These include, for example, the Russian Methodological and Training Center (RMTC), at Obninsk, Russia, (information at <http://www.rmtc.obninsk.ru/en/>), which provides training for technical experts in nuclear material

Incident: Intrusion at Pelindaba, South Africa, 2007

On the night of November 8, 2007, two teams of armed men attempted to break in to the nuclear research center at Pelindaba, South Africa, where hundreds of kilograms of weapon-grade HEU left over from South Africa's nuclear weapons program are stored.¹ One of the teams got through a 10,000-volt security fence and disabled the intrusion detectors without setting off any alarm. They then proceeded to the emergency control center, the central routing point for most of the site's other alarm systems. There, they entered a second-story window, got into a struggle with Anton Gerber, who they shot in the chest—and who raised the first alarm, calling site security for help.²

The attackers left via the same point at the fence by which they arrived, reportedly spending 45 minutes inside the guarded perimeter without ever being engaged by site security forces (despite Gerber's call to them). The other team, approaching on another side of the facility, engaged the site security forces, but never entered the site perimeter; it is possible that this other team was intended as a diversion, or to take part in some aspect of the plan that did not come to fruition (perhaps having been interrupted by Gerber calling the site security forces). The attackers' familiarity with how to disable the intrusion detectors and with equipment at the emergency control center strongly suggests they had help from someone with insider knowledge. The security manager, two guards, and a shift supervisor on duty at the time resigned or were fired. While the intruders never penetrated the inner security for the HEU area, this incident represents a major security breach, highlighting substantial weaknesses in the site's detection, assessment, and response arrangements at the time. Since then, the site has implemented substantial security upgrades, in part with US technical advice and assistance.³ The intruders have never been identified or captured.

Lesson: This event makes clear that nuclear security systems must be designed to cope with adversary threats that include well-trained armed intruders operating as more than one team and using insider knowledge of the security system and its weaknesses.

¹ For a description of this event, see Bunn, *Securing the Bomb* 2008, pp. 3-4 (with sources cited therein), and "60 Minutes: Assault on Pelindaba," CBS News, November 23, 2008.

² Michael Wines, "Break-In at Nuclear Site Baffles South Africa," *New York Times*, November 15, 2007, <http://www.nytimes.com/2007/11/15/world/africa/15joburg.html> (accessed March 7, 2014).

³ Frans Mashilo, site security manager, personal communications, July 2011.

on the job, and most did not require any certification that they in fact had all the knowledge they needed to do their jobs.

Training has become a major focus during the four-year effort. Many countries have established or are establishing "Centers of Excellence" in nuclear security (or, in some cases, on broader nuclear issues, with nuclear security one part of a broader mission).¹⁴² One of the Russian centers

accounting, control, and physical protection systems; the Interdepartmental Special Training Center (ISTC), also in Obninsk, which provides training for guard forces; and the George Kuzmycz Training Center for Physical Protection, Control, and Accounting of Nuclear Material, (information at <http://www.mpca.kiev.ua>).

¹⁴² Alan Heyes, "An Assessment of the Nuclear Security Centers of Excellence" (Muscatine, Iowa: Stanley Foundation, May, 2012), <http://www.stanleyfoundation.org/publications/pab/AlanHeyesPAB512.pdf> (accessed March 8, 2014).

has opened its doors to students from all IAEA member states.¹⁴³ In addition to training, these centers often have the effect of creating an institution that concentrates people who believe in the importance of nuclear security; that in itself can lead to an increased national focus on improving nuclear security.

The IAEA has greatly expanded the nuclear security training it offers to member states, which now includes over 80 courses training some 2,000 participants a year. Several of these courses are now available in online formats.¹⁴⁴ The IAEA's Division of Nuclear Security has sought to coordinate the efforts of the national centers of excellence (many of which will provide training based on materials developed by the IAEA); and has launched the "International Nuclear Security Education Network," (INSEN) a coalition of academic institutions, international organizations, and nuclear material management associations focused on training and education related to nuclear security. INSEN has produced curriculum materials for a master's degree program and a certificate program in nuclear security, and in 2012, Delft University in the Netherlands became the first to offer a master's degree program in nuclear security using this curriculum.¹⁴⁵

No central organization is ensuring that all of these training courses provide the quality and type of training that is most needed. In particular, WINS has identified training for managers overseeing nuclear security as a key gap, and is working to establish the "WINS Academy," in which WINS would offer educational materials and provide accreditation to programs whose training meets WINS standards. WINS estimates that there are some 100,000–150,000 managers worldwide with responsibilities for nuclear security, and that some ten percent of these might turn over every year, creating a demand for training of 10,000–15,000 new people in these roles every year.¹⁴⁶

A key question remains, however: are all of these training programs in fact ensuring that security and accounting staff at key facilities have all the knowledge and skills they need to achieve effective nuclear security? Are the training programs helping to build and sustain an effective nuclear security culture in the organizations where the trainers work? The data to answer these questions fully are simply not available. A superficial impression from interviews with experts in several governments and visits to nuclear facilities is that at least some of this training is having significant benefits for reducing the risk of nuclear theft. In addition to training in particular skills, however, there should be an increased emphasis on training that highlights plausible threats against which security systems must protect, including discussions of the kinds of incidents that have already occurred, and which demonstrate the capabilities and tactics adversaries may use in an attempt to steal nuclear weapons or the materials needed to make them.

¹⁴³ "Synergy in Nuclear Security: Russia Opens World's First International Nuclear Security Training Centre" (Vienna: IAEA, April 9, 2010), <http://www.iaea.org/newscenter/news/2010/nucsecurity.html> (accessed March 8, 2014).

¹⁴⁴ Information provided by IAEA officials, March 2014.

¹⁴⁵ "New Masters Programme in Nuclear Security is Launched at Delft University of Technology" (Vienna, IAEA, April 18, 2013), <http://www.iaea.org/newscenter/news/2013/nsdelft.html> (accessed March 8, 2014). While this is the first master's program using the curriculum developed by INSEN, the Moscow Engineering Physics Institute (MEPhI) launched a master's program on material protection, control, and accounting in 1998 with US financial assistance. Tomsk Polytechnic has a related program.

¹⁴⁶ Roger Howsley, *The WINS Academy Strategy for 2013–2015*.

Progress on Strengthening the Global Regime

For decades, the United States and many other countries, along with international organizations such as the IAEA, have sought to strengthen the global framework for nuclear security. What progress has the last four years seen in this effort—in establishing means to identify common goals; motivate states to make commitments to take steps to achieve those goals; and track progress toward those goals? Are we now better able to find and fix the weakest links in nuclear security around the world?

President Obama’s four-year initiative has transformed the international discussion of nuclear security. Nuclear security is now a far more important focus of government agencies and publics around the world. Twenty years ago, the IAEA considered it a great success to hold a meeting on nuclear security with 40 to 50 participants, representing perhaps 10 countries, mostly at the level of a deputy director of a nuclear facility. In July 2013, the IAEA hosted a meeting on nuclear security that drew over 1,300 participants from 125 countries and almost two dozen intergovernmental and nongovernmental organizations. The meeting included both a ministerial gathering and sessions with technical experts. International awareness of the nuclear security issue has both deepened and spread.

The new awareness has helped to strengthen the international nuclear security framework—the collection of treaties, institutions, voluntary collectives, and norms intended to promote action to strengthen nuclear security.¹⁴⁷ Progress is evident over the last several years, but the governance of nuclear security at the international level remains weak and uneven. There are no specific global standards for how secure nuclear weapons or weapons-usable nuclear material should be; no inspections, verification, or even standardized self-reporting mechanisms to build confidence that states are fulfilling their nuclear security obligations; and no agreed-upon forum for continuing a high-level dialogue on nuclear security after the summit process ends in 2016. It is clear that much work remains.

A Growing IAEA Nuclear Security Role

An effective global nuclear security effort for the long term is likely to require multiple institutions. But the IAEA, as the world’s principal international organization focused on nuclear issues, will inevitably play a central role.

During the four-year effort, the IAEA’s nuclear security role has expanded significantly and gained much wider acceptance. A few years ago, many IAEA member states were quick to point out that nuclear security was never mentioned in the IAEA Statute and argued that this issue lay beyond the Agency’s mandate and should not be funded in the IAEA regular budget. Times have changed. At the July 2013 IAEA conference on nuclear security, the assembled ministers and senior officials unanimously expressed “support” for “the IAEA’s continuing work” to help states strengthen nuclear security and emphasized the IAEA’s “central role” in “strengthening the

¹⁴⁷ There is some dispute over whether to call the set of nuclear security agreements, resolutions, recommendations, and initiatives a “regime,” a “framework,” or an “architecture.” Robert Keohane and David Victor have described the somewhat similar collection of agreements and initiatives focused on climate change as a “regime complex,” emphasizing that no one agreement or regime is likely to be able to encompass all the efforts needed to solve the problem – which is likely also the case for nuclear security. See “The Regime Complex for Climate Change,” *Perspectives on Politics*, Vol. 9, No. 1 (March 2011), pp. 7–23.

nuclear security framework globally.”¹⁴⁸ In late 2013, the Office of Nuclear Security became a full division within the Department of Safety and Security, elevating the status of the Agency’s role in strengthening security and providing the bureaucratic “headroom” inside the IAEA for further growth. Today the IAEA contributes to strengthening nuclear security in a variety of ways, including promoting nuclear security norms and principles; assisting with the implementation of treaty obligations; providing guidance and recommendations to member states through the nuclear security publication series; coordinating other efforts ranging from the network of Centers of Excellence to donor states’ efforts to assist with nuclear security; and serving as a forum for multilateral discussion of nuclear security.¹⁴⁹ An increasing portion of the budget for the IAEA’s nuclear security activities comes from the agency’s regular budget; the nuclear security division received an 11 percent increase in funding in the regular budget for the current year.¹⁵⁰ Regular budget funding is important because voluntary contributions are difficult to predict and often tied to particular projects of interest to the donor, making it difficult for the Division of Nuclear Security to plan and prioritize.

In 2012, the IAEA Board of Governors approved a set of “Nuclear Security Fundamentals,” which will serve as the primary statement of principles upon which more specific IAEA recommendations and implementing guides for nuclear security rest.¹⁵¹ The IAEA nuclear security fundamentals build upon fundamental principles that were first enunciated in 2001, and were incorporated in modified form in the 2005 Amendment to the Convention on Physical Protection of Nuclear Materials (see below).¹⁵² The new IAEA fundamentals cover a broader scope, going beyond physical protection, and provide somewhat more detail on certain points. Notably, they declare as a fundamental principle the need for high-level leadership on nuclear security, they emphasize the need to minimize insider threats, and they mention the importance of cyber security for protecting nuclear materials. The publication of fundamental principles are a welcome development, but are mute on most of the specifics that are crucial to effective nuclear security—such as the kinds of threats against which nuclear weapons and the materials needed to make them should be protected.

More detail can be found in the IAEA’s recommendations for physical protection of nuclear materials and facilities. In 2011—for the first time since the 9/11 attacks—member states completed a revision of the IAEA main physical protection recommendations, known as Information Circular (INFCIRC) 225, Revision 5.¹⁵³ INFCIRC/225/Rev. 5 recommends, for example, that states

¹⁴⁸ “International Conference on Nuclear Security: Ministerial Declaration” (Vienna: IAEA, July 2013).

¹⁴⁹ Trevor Findlay, “The IAEA’s Nuclear Security Role,” Discussion Paper (Nuclear Threat Initiative, July 2013), https://www.nti.org/media/pdfs/IAEA_Nuclear_Security_Role_3.pdf (accessed February 2, 2014).

¹⁵⁰ International Atomic Energy Agency, *The Agency’s Programme and Budget 2014–2015*, GC(57)/2 (Vienna: IAEA, August 2013), http://www.iaea.org/About/Policy/GC/GC57/GC57Documents/English/gc57-2_en.pdf (accessed January 30, 2014).

¹⁵¹ International Atomic Energy Agency, *Objective and Essential Elements of a State’s Nuclear Security Regime: Nuclear Security Fundamentals*, Nuclear Security Series No. 20 (Vienna: IAEA, 2013), http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1590_web.pdf (accessed February 2, 2014).

¹⁵² For the original version, see International Atomic Energy Agency, “Nuclear Verification and Security of Material: Physical Protection Objectives and Fundamental Principles,” GOV/2001/41 (Vienna: IAEA, August 15, 2001), <http://www.iaea.org/About/Policy/GC/GC45/Documents/gc45inf-14.pdf> (accessed March 8, 2014).

¹⁵³ International Atomic Energy Agency, *Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities*, INFCIRC/225/Revision 5 (Vienna: IAEA, 2011), http://www-pub.iaea.org/MTCD/publications/PDF/Pub1481_web.pdf (accessed February 3, 2012).

should require that all facilities or transporters with a “Category I” quantity of weapons-usable nuclear material—the amount requiring the highest level of security—provide protection against a specified DBT; it calls for the first time for states to use realistic “force-on-force” exercises to test the performance of their nuclear security systems; and it greatly expands the coverage of protecting nuclear facilities against sabotage.¹⁵⁴ In one major change, the new recommendations suggest that states should not consider lightly irradiated nuclear material—such as irradiated fuel from most research reactors—to be “self protecting” if a state faces adversaries who are “willing to commit a malicious act.”¹⁵⁵ The IAEA’s recommendations on physical protection are the closest thing to a global nuclear security standard that exists today. While these guidelines are purely advisory, many states incorporate them into their regulations, and indeed, the United States and a number of other nuclear suppliers require that all the nuclear materials they supply be protected at least in accordance with these recommendations. In a recent survey of nuclear experts from many of the countries with HEU or separated plutonium, international recommendations were rated as one of the more important factors leading to change in countries’ nuclear security policies.¹⁵⁶

Nevertheless, while more detailed than many of the other elements of the nuclear security framework, the revised IAEA recommendations are still quite vague. For example, the recommendations specify that “Category I” nuclear material should be behind a fence with intrusion detectors around the area where such material is handled, but say nothing about how difficult it should be to bypass the intrusion detectors. It is not necessary for a Category I site to have any armed guards to comply with the IAEA recommendations (and some countries still do not have armed guards at nuclear facilities), though if a state does not have armed guards, it is recommended that it take other measures to compensate.

Beyond INFCIRC/225/Rev. 5, the IAEA has an expanding “Nuclear Security Series,” which now offers recommendations and technical guidance on a wide range of topics, from finding lost radiological sources to strengthening nuclear security culture and protecting against insider threats. These documents are helping many countries shape their approaches to nuclear security. The reality is that many countries with only a small nuclear infrastructure have few experts on nuclear security; nuclear security regulators have often been reassigned from nuclear safety. Having guidance from an international agency on how to approach key nuclear security problems is often extremely helpful to them. Over time, the IAEA hopes to see documents in this series accepted as standards, as safety recommendations are, giving them more normative status.

In addition to recommendations, the IAEA also offers nuclear security services, which states can voluntarily take up, including peer reviews of nuclear security arrangements and assistance in improving nuclear security. States are taking advantage of these services in greater numbers than ever before. For example, the IAEA’s most important type of nuclear security review is the International Physical Protection Advisory Service (IPPAS); until recently, IPPAS missions were only requested by developing countries or states transitioning from communism, but in recent years, even countries that consider themselves advanced can benefit substantially from an inde-

¹⁵⁴ A “Category I” quantity is two kilograms of separated plutonium or U-233, or five kilograms of U-235 contained in HEU.

¹⁵⁵ For a summary of revisions and the process that led to them, see Christopher Price, “Development of the IAEA Nuclear Security Recommendations on Physical Protection of Nuclear Materials and Nuclear Facilities (INFCIRC/225/Rev.5),” *Journal of Nuclear Materials Management*, Vol. 39, No. 3 (Spring 2011).

¹⁵⁶ Bunn and Harrell, *Threat Perceptions and Drivers of Change in Nuclear Security*, p. 7.

pendent review of their approaches and advice on how to improve them. The Netherlands, host of the upcoming summit, has hosted a record four IPPAS visits, and during the four-year effort the United States, the United Kingdom, and France became the first nuclear weapon states to host such missions—with the UK IPPAS mission reviewing security for the Sellafield site, where over 100 tons of separated plutonium are stored, by far the most important facility any IPPAS mission has ever reviewed.¹⁵⁷ The United States hosted its first IPPAS mission at the HEU-fueled reactor managed by the National Institute of Standards and Technology in October 2013.¹⁵⁸ By early 2014, the IAEA had conducted 62 IPPAS missions.¹⁵⁹ An ad hoc panel established by the European Union (EU) has called on all its members to request these peer review assessments of elements of national nuclear security structures.¹⁶⁰

The IAEA has also stepped up its International Nuclear Security Advisory Service, which, upon request, “carries out peer reviews and advisory services to evaluate the effectiveness of nuclear security systems and measures related to material out of regulatory control.”¹⁶¹ In addition, the agency is prioritizing assistance to members in the development and implementation of what it calls “integrated nuclear security support plans.” By mid-2013, 47 states had approved nuclear security plans, an additional 30 states were in the process of approving or preparing plans for approval, and dozens more had asked for IAEA help in preparing such plans, bringing the total number of states taking advantage of this service to well over a hundred—a strong majority of the IAEA’s member states.¹⁶²

Ratifications of Nuclear Security-Related Conventions

There are several legally binding treaties aimed at strengthening nuclear security, and states’ acceptance of these treaties and conventions has increased since the beginning of the Obama administration’s four-year effort. The Convention on the Physical Protection of Nuclear Materials (CPPNM) includes useful provisions on criminalizing nuclear theft and smuggling, giving all parties jurisdiction to prosecute such crimes, although its physical protection provisions apply only to material in international transport. In 2005, the convention was amended to extend its terms to cover materials in domestic use, storage, and transport, and to cover sabotage of nuclear facilities as well as nuclear theft. The 2005 amendment also includes a list of “fundamental principles of physical protection” that the IAEA’s 2013 “fundamentals” publication built upon. Though an important element of the nuclear security framework, the amended convention’s

¹⁵⁷ UK Department of Energy and Climate Change, “Nuclear Security Mission to Sellafield and Barrow Completed” (London: DECC, October 28, 2011), <https://www.gov.uk/government/news/nuclear-security-mission-to-sellafield-and-barrow-completed> (accessed March 8, 2014).

¹⁵⁸ International Atomic Energy Agency, “IAEA Completes Nuclear Security Review Mission in United States,” October 11, 2013, <http://www.iaea.org/newscenter/pressreleases/2013/prn201318.html> (accessed March 6, 2014).

¹⁵⁹ Information provided by the IAEA, March 2014 (accessed March 8, 2014). See also International Atomic Energy Agency, “Nuclear Security Report 2013,” GOV/2013/36-GC(57)/16 (Vienna: IAEA, August 6, 2013), http://www.iaea.org/About/Policy/GC/GC57/GC57Documents/English/ge57-16_en.pdf (accessed February 2, 2014).

¹⁶⁰ Ad Hoc Group on Nuclear Security, *Report of the Ad Hoc Group on Nuclear Security*, 10616/12 (Brussels: European Union, May 31, 2012).

¹⁶¹ IAEA, “Nuclear Security Report 2013.”

¹⁶² See IAEA, “Nuclear Security Report 2013,” and Khammar Mrabit, “International Cooperation: The Role & Activities of the IAEA,” presentation to the “International Conference on Nuclear Security: Enhancing Global Efforts,” Vienna, Austria, July 4, 2013.

Table 1: States with Weapons-Usable Nuclear Material That Have Not Joined Nuclear Security Treaties

ICSANT	CPPNM
Argentina	Iran*
Ghana	North Korea*
Iran	Syria*
Israel	CPPNM Amendment
Italy	Belarus
North Korea*	Iran
Norway	Italy
Pakistan*	Japan
Sweden	North Korea
Syria	Pakistan
United States	South Africa
Vietnam*	Syria
	United States

**Indicates the state has neither signed nor ratified; amendments to treaties are not signed separately.*

requirements are very general. It says, for example, that countries should set national rules for nuclear security; but it says nothing about what those rules should be.¹⁶³ The International Convention on the Suppression of Acts of Nuclear Terrorism (ICSANT) entered into force in 2007. It defines and criminalizes nuclear terrorism, requiring 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 take into account relevant IAEA recommendations.¹⁶⁴

Over the period of the four-year effort, there has been significant progress on getting more states to join the conventions and accept the 2005 amendment. Of the 72 states that had acceded to the amendment by early 2014, 49 did so during the four-year effort.¹⁶⁵ Although the leaders gathered at the Seoul nuclear security summit set a goal of getting enough ratifications to bring the amendment into force “by 2014,” as of early 2014 some 28 additional ratifications are still needed—and the United States, which proposed the amendment, is not among the states that has ratified it. Similarly, 40 additional states have joined ICSANT in the past four years, bringing the

¹⁶³ 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), <http://www.iaea.org/About/Policy/GC/GC49/Documents/gc49inf-6.pdf> (accessed January 31, 2014).

¹⁶⁴ For the text of the convention, see United Nations, *International Convention for the Suppression of Acts of Nuclear Terrorism* (New York: United Nations, 2005), http://www.un.org/ga/search/view_doc.asp?symbol=A/Res/59/290 (accessed January 28, 2014).

¹⁶⁵ For the text and status of the 2005 amendment see International Atomic Energy Agency, *Amendment to the Convention on the Physical Protection of Nuclear Material* (Vienna, IAEA, updated 10 January 2014), http://www.iaea.org/Publications/Documents/Conventions/cppnm_amend_status.pdf (accessed February 2, 2014).

total number of parties to 92 by early 2014.¹⁶⁶ Ten additional parties also signed up to the original CPPNM.¹⁶⁷ An important interim step would be a pledge by all states at the 2014 Nuclear Security Summit voluntarily to implement fully the conventions as amended even before they are ratified or enter into force.

Most of the states with HEU or separated plutonium on their soil have now accepted the 2005 amendment to the CPPNM. Two years ago there were 19 such states with weapons-useable material that had not ratified; today there are only nine. Belgium, Canada, France, and Israel are among the most recent to accept the amendment. Embarrassingly, the United States has pledged to ratify ICSANT and the 2005 CPPNM amendment at each of the past two summits and has failed to deliver on that promise to date. It joins Belarus, Japan, Iran, North Korea, Pakistan, and South Africa on the list of key laggards.¹⁶⁸

Renewed and Expanded Security Council Resolutions

In September 2009, the four-year effort was given an important boost in international legitimacy when it was made part of UN Security Council Resolution (UNSCR) 1887, which called on all states to raise standards of nuclear security, share best practices, minimize the use of HEU, and take new steps to interdict nuclear smuggling. UNSCR 1887, however, urged and cajoled states to act—it was not legally binding.

By contrast, UNSCR 1540, approved unanimously in 2004, legally obligates all states to provide “appropriate effective” security and accounting for all nuclear weapons or related materials, along with export and border controls, and, among other measures, to report to the Security Council on their efforts. No one, however, has yet developed an agreed-upon definition of what essential elements must be in place to comply with these requirements.¹⁶⁹ In 2011, the Security Council extended the life of the committee that oversees the implementation of UNSCR 1540 for another 10 years. The committee’s new broadened mandate includes identifying “effective practices” and providing states with guidance and templates for implementation. Toward that end, in 2013, Croatia hosted a seminar attended by ten OSCE countries on identifying effective practices, and Croatia and Poland conducted mutual visits in a “peer review” exercise to share and report on effective practices — though it is not clear that either of these activities focused

¹⁶⁶ United Nations, “International Convention on the Suppression of Acts of Nuclear Terrorism,” United Nations Treaty Collection, Databases, Chapter XVIII, 15, (New York: United Nations, 2014), http://treaties.un.org/Pages/ViewDetailsIII.aspx?&src=UNTSO&mtdsg_no=XVIII~15&chapter=18&Temp=mtdsg3&lang=en#Participants (accessed Feb 2, 2012).

¹⁶⁷ International Atomic Energy Agency, *Convention on the Physical Protection of Nuclear Material* (Vienna: IAEA, December 2013), http://www.iaea.org/Publications/Documents/Conventions/cppnm_status.pdf (accessed February 24, 2014).

¹⁶⁸ Although Japan has not signed on to the 2005 amendment, it has taken a number of steps to implement the latest revision of the IAEA’s physical protection guidelines, including the creation in late 2012 of a new and independent regulatory agency and the enactment of important additional protections on Category I material wherever it is found. See Toru Iida, “Enhancement of Physical Protection Measures at JAEA based on the Revised Regulation Reflecting the Accident of Fukushima Daiichi NPP and INFCIRC/225/Revision 5” (presentation, IAEA International Conference on Nuclear Security Vienna, Austria, July 1-5, 2013). The standard of physical protection in the United States generally meets or exceeds the requirements in the 2005 CPPNM amendment as well.

¹⁶⁹ The text of UNSCR 1540, along with many related documents, can be found at United Nations, “1540 Committee” (New York: UN), <http://www.un.org/sc/1540/> (accessed February 22, 2010).

significantly on nuclear security (particularly as Croatia has no significant nuclear infrastructure).¹⁷⁰ In 2013, UNSCR 2118, focused on the Syrian chemical weapons crisis, legally obligated all states to report any violation of UNSCR 1540.¹⁷¹

The committee charged with overseeing implementation of UNSCR 1540 has only a few staff and has been able to play only a very limited role in ensuring that states fulfill their UNSCR 1540 obligations. In the early years after UNSCR was approved, the committee focused primarily on reviewing and reporting to the Security Council on the reports states sent in about their implementation of the resolution (which varied enormously in quality and detail); the committee simply has not had the resources to go and review states' actual implementation on the ground. More recently, the committee has been helping to match states in need of assistance with donor states with expertise and resources and helping to improve states' understanding of what UNSCR 1540 requires. Nevertheless, implementation of 1540 is uneven; while most states have at least some legislative framework in place relating to accounting of nuclear materials, for example, only a minority of states had any such framework in place for securing or protecting such materials as of 2011.¹⁷² Some 22 states have still never provided the committee with a single report. The committee has expressed the hope to achieve universal compliance with 1540's reporting requirements by the end of 2014, on the ten-year anniversary of the resolution, though even this modest goal may turn out to be out of reach.

Extended and Expanded Cooperative Initiatives

Much of the most important work to improve nuclear security in the last two decades has taken place through bilateral and multilateral cooperative initiatives, such as US-funded cooperative threat reduction efforts (originally known as Nunn-Lugar, after the Senators who sponsored the legislation). A number of these efforts have been extended and expanded during the four-year effort. These coalitions of like-minded states help increase states' capacity to provide effective nuclear security.

The G8 established the Global Partnership Against the Spread of Weapons and Materials of Mass Destruction in 2002, with the aim of providing \$20 billion over ten years for threat reduction efforts, primarily in Russia and the states of the former Soviet Union.¹⁷³ In 2011, in the midst of the four-year effort, the participants agreed to extend the partnership for another ten years and expand

¹⁷⁰ 1540 Committee, "Letter dated December 24, 2013 from the Chair of the Security Council Committee established pursuant to resolution 1540 (2004) addressed to the President of the Security Council," S/2013/769 (New York: UN, 26 December 2013), http://www.un.org/en/ga/search/view_doc.asp?symbol=S/2013/769 (accessed March 8, 2014).

¹⁷¹ 1540 Committee, "Letter dated December 24."

¹⁷² 1540 Committee, "Letter dated 12 September 2011 from the Chair of the Security Council Committee established pursuant to resolution 1540 (2004) addressed to the President of the Security Councils," S/2011/579 (New York: UN), http://www.un.org/en/ga/search/view_doc.asp?symbol=S/2011/579 (accessed March 8, 2014).

¹⁷³ Alan Heyes, "The Global Partnership on WMD: A Work in Progress," *Arms Control Today* (April 2013), http://www.armscontrol.org/act/2013_04/The-Global-Partnership-on-WMD-A-Work-in-Progress#2 (accessed March 8, 2014); Kelsey Davenport, "Global Partnership Revamped in 2012," *Arms Control Today* (January/February 2013), http://www.armscontrol.org/act/2013_01-02/Global-Partnership-Revamped-in-2012 (accessed March 8, 2014); Michelle Cann et al., *The Nuclear Security Summit: Progress Report* (Washington, D.C.: Arms Control Association and Partnership for Global Security, July 2013), http://pgstest.files.wordpress.com/2013/06/nuclear_security_summit_report_2013.pdf (accessed March 8, 2014), p. 13.

it to help countries around the world strengthen nonproliferation controls, including those mandated by UNSCR 1540, with nuclear security a key priority.¹⁷⁴ Unfortunately, however, states did not agree on new targets for funds for the initiative.¹⁷⁵ The Global Partnership has increased its membership to 25 countries.¹⁷⁶ However, it is unclear whether the G8 and other Global Partnership members will be able to continue to maintain a sharp focus, with a clear portfolio of projects, supported by resources on a scale resembling its first decade. As a result of the situation in Ukraine, the next G8 Summit, in June 2014, to be held in Sochi Russia is itself now in doubt.

The Global Initiative to Combat Nuclear Terrorism (GICNT) was launched by the United States and Russia in 2006, and they remain the co-chairs. It has focused primarily on capacity-building, organizing exercises, and workshops in a wide variety of areas related to preventing nuclear terrorism. It has generally not focused specifically on helping states upgrade their nuclear security measures. And unlike the Global Partnership, it was not designed to be a major mechanism for channeling nuclear security funding. GICNT has contributed modestly to strengthening the international nuclear security framework. Members, now 85 nations in all, endorse a statement of principles, and most recently have adopted documents introduced by GICNT working groups on fundamentals of nuclear forensics, guidelines for integrating training and exercises into national nuclear detection architecture, and guidelines for strengthening nuclear detection.¹⁷⁷ Although the Obama administration sought to strengthen the initiative, and Obama himself pledged in the Prague speech that launched the four-year effort to turn the Global Initiative into a “durable” institution, the membership has only increased by ten states over the past four years, and efforts to further institutionalize the initiative have not materialized.¹⁷⁸

As noted earlier, during the four-year effort, one of the most important and long-standing cooperative initiatives—US-Russian cooperation on nuclear security—has, in some respects, weakened. The Russian government has increasingly insisted that this cooperation is no longer needed, and the original Nunn-Lugar agreement was replaced with a pact that excluded the Ministry of Defense entirely (though it provided a strengthened legal foundation for several other aspects of cooperation, such as consolidating nuclear material and converting research reactors). In both Washington and Moscow, there is less support than there once was for working together to improve nuclear security in the interests of both countries and the international community—but that work is still much needed.

¹⁷⁴ See Nuclear Threat Initiative, “Global Partnership Against the Spread of Weapons and Materials of Mass Destruction,” online, <http://www.nti.org/treaties-and-regimes/global-partnership-against-spread-weapons-and-materials-mass-destruction-10-plus-10-over-10-program/> (accessed March 8, 2014).

¹⁷⁵ Nuclear Threat Initiative, “Global Partnership Against the Spread of Weapons and Materials of Mass Destruction.”

¹⁷⁶ Davenport, “Global Partnership Revamped in 2012.”

¹⁷⁷ “2013 Global Initiative to Combat Nuclear Terrorism Plenary Meeting Joint Co-Chair Statement,” May 24, 2013, <http://www.state.gov/t/isn/rls/prsr/2013/210575.htm> (accessed May 24, 2012).

¹⁷⁸ For background including the current list of GICNT members, see Nuclear Threat Initiative, “Global Initiative to Combat Nuclear Terrorism,” <http://www.nti.org/treaties-and-regimes/global-initiative-combat-nuclear-terrorism-gicnt/> (accessed March 8, 2014). For the latest report from the Initiative’s co-chairs, see “2013 Global Initiative to Combat Nuclear Terrorism Plenary Meeting Joint Co-Chair Statement” on the Global Initiative website, <http://www.gicnt.org/download/meetings/2013%20Joint%20Co-Chair%20Statement.pdf> (accessed March 8, 2014).

The Nuclear Security Summit Process

The nuclear security summits have been the Obama administration's signature innovation in global nuclear security governance. They have been remarkable in succeeding in bringing political leaders from around the world—including Arabs and Israelis, India, and Pakistan, and other long-time adversaries—and getting them to focus on nuclear security and work constructively together to improve it. The nuclear security summit process has played at least five critical roles:

- **Raising the issue to a high political level.** Many things that could not get done at working levels where nuclear security has previously been discussed could now get done—at least in principle. Many more countries, for example, have ratified the relevant conventions than likely would have been the case had the summits never taken place. And the process of discussion leading up to each summit has surfaced many issues that otherwise would never have been raised (both between governments and within them). As just one example: the complications of packaging and moving the small amount of plutonium that had been in Sweden for decades and getting acceptance for bringing it to secure storage in the United States had long been in the “too hard” category, and no one had been doing much about it—but pressure from the top of the Swedish government was enough to make it happen, and Sweden no longer has any weapons-usable nuclear material on its soil.¹⁷⁹
- **Increasing awareness of the nuclear terrorism threat.** The opening line of the Washington nuclear security summit communiqué affirms that “Nuclear terrorism is one of the most challenging threats to international security.” The leaders said much the same in Seoul, and can be expected to repeat the point in The Hague. With the process of preparing for the summit combined with new IAEA recommendations emphasizing the need for every country with nuclear facilities and materials to carry out a threat assessment, awareness of the nuclear terrorism threat has expanded significantly. At The Hague summit, the leaders will take part in a scenario of a nuclear terrorism crisis; participating in such exercises can often reach people emotionally in a way that reading papers and receiving briefings cannot. Unfortunately, except for a briefing one of the authors (Tobey) provided for the last Sherpa meeting in the lead-up to The Hague summit, the process has not yet included detailed discussions of the specifics of the threats of nuclear and radiological terrorism, theft, and smuggling.¹⁸⁰
- **Providing a regular forum for high-level dialogue on next steps.** While there are a variety of forums for discussing nuclear arms reductions, nuclear safety, or nuclear nonproliferation, there had never before been a regular forum in which leaders (or even high-level officials) could discuss what needed to be done to strengthen nuclear security. At each summit, the dialogue has led to new issues and goals being emphasized.
- **Creating moments for action.** The practice of states bringing “house gifts” to the summit—the idea that all or most of the leaders attending would announce something their country would do to improve nuclear security—has been one of the most important innovations of the nuclear security summit process. Unlike the summit communiqués, which

¹⁷⁹ White House, Office of the Press Secretary, “Fact Sheet: Plutonium Removal from Sweden.” (Washington, D.C., March 2012), <http://www.whitehouse.gov/the-press-office/2012/03/26/fact-sheet-plutonium-removal-sweden> (accessed on February 24, 2014).

¹⁸⁰ See Tobey and Zolotarev, *The Nuclear Terrorism Threat*.

tend toward the least common denominator because any country can object, house gifts only require one government to decide. Leaders' desire for deliverables to announce at the summit has forced through many decisions that might otherwise have languished for years. The house gifts have ranged from groundbreaking—such as Ukraine's decision to eliminate all of its HEU (including one site with enough high-quality HEU for a terrorist gun-type bomb)—to extremely modest, such as Belgium's pledge to contribute \$300,000 to the IAEA's nuclear security fund. For the second nuclear security summit in Seoul, the idea evolved further to include “gift baskets” —commitments made by groups of countries, rather than just individual states. The list of particular actions countries have taken in the context of the nuclear security summits is long.¹⁸¹

- **Provoking new interagency discussions.** In many cases, the nuclear security summits have gotten agencies within countries talking to each other in ways they never had before, in order to develop their countries' approaches in preparation for the summits.

The nuclear security summit process has also had important weaknesses. First, from the beginning, negotiators adopted a consensus approach to drafting the communiqués in which every country had a veto. This resulted in somewhat watered-down texts with many phrases that allowed countries to opt out of the commitments (such as “to the extent practicable” or “as appropriate”); in themselves, the communiqué will likely have little effect on nuclear security around the world, despite the importance of the overall process. The use of such opt-out phrases, however (and the separation of the detailed items addressed at the first summit into a “work plan” separate from the broad principles of the communiqué in the Washington nuclear security summit statement) made it possible to find wording that allowed key issues to at least be raised and endorsed in general terms without every participating country being willing to commit to implement them.

Second, the summit process has been exclusive rather than inclusive—only a limited set of countries was invited. This was essential to be able to make progress, but it provoked resentment from non-participants and a general sense of a lack of political legitimacy. (Some IAEA member states, for example, criticized the IAEA for even attending as an observer—and the consensus statement from the IAEA nuclear security conference in 2013 did not even explicitly acknowledge the existence of the summit process.)¹⁸² The countries participating have included almost all, but not all, of the countries with plutonium or HEU to protect (particularly notable non-participants include North Korea, Iran, and Belarus).

Third, the nuclear security summits have not sought to build any new institutions or initiatives to strengthen the global nuclear security framework. Negotiators have largely considered agreement on a new convention or institution as too difficult, and have focused instead on strengthening the elements of the framework that already exist.¹⁸³

¹⁸¹ Michelle Cann et al., *The Nuclear Security Summit: Assessment of Joint Statements* (Washington, D.C.: Arms Control Association and Partnership for Global Security, March 2014), http://www.armscontrol.org/files/ACA_NSS_Report_2014_FINAL.pdf (accessed March 8, 2014).

¹⁸² “Ministerial Declaration,” (Vienna: Austria, International Conference on Nuclear Security: Enhancing Global Efforts, 1–5 July 2013), <http://www-pub.iaea.org/MTCD/Meetings/PDFplus/2013/cn203/cn203MinisterialDeclaration.pdf> (accessed March 8, 2014).

¹⁸³ Some states and some analysts would like to see a framework convention that would tie together the various ele-

Table 2: Progress on Risk Reduction During the Four-Year Effort

Security Goals	Progress
Security Upgrades	Substantial, though significant upgrades are still needed in a number of countries, and risks may be increasing in Pakistan as it expands its arsenal and moves toward tactical nuclear weapons.
Reducing the Number of Sites	Significant, especially with respect to civilian HEU, but there are still far too many sites with civilian HEU, there has been little progress on civilian plutonium, and only modest progress on military stocks.
Security Culture, Best Practices, and Training Programs	Significant, though difficult to assess. Substantial further work—including full operation of the WINS Academy—is still needed.
Strengthening Nuclear Security Framework	Significant, particularly from developments at the IAEA and the nuclear security summit process. But the overall framework remains weak.

Finally, the major powers—including the United States—have made only modest efforts to use carrots, sticks, and other tools of diplomacy to convince states to commit to high standards of security or to eliminate particular stockpiles. The contrast between the determined, sustained, high-level effort to craft an effective global sanctions regime against Iran and the far more modest effort to convince states to act on nuclear security is very sharp.

It now seems likely that the 2016 nuclear security summit in Washington will be the last biennial gathering. Senior political leaders are only willing to keep gathering on the same topic for so long—and with the past summits having already agreed or found insurmountable obstacles to agreement on most of the key topics, each summit faces a higher hurdle than the last to find really important areas where new progress can be made. But the job is not done in 2014, and will not be done in 2016. There will surely be a need for many years to come for some form of continued high-level dialogue on next steps in improving nuclear security.¹⁸⁴

ments of the global framework into a more coherent whole, but so far there appears to be little prospect for negotiating such an agreement. For a discussion of a framework convention, see *Responsibility Beyond Rules: Leadership for a Secure Nuclear Future* (Washington, D.C.: Nuclear Security Governance Experts Group, March 2013), <http://www.nsg.eg.org/recommendations.cfm> (accessed March 6, 2014).

¹⁸⁴ For an analysis of progress and weaknesses in the nuclear security summit process, see Ken Luongo, “Endgame for the Nuclear Security Summits,” *Arms Control Today* (January 2014), http://www.armscontrol.org/act/2014_01-02/Endgame-for-the-Nuclear-Security-Summits (accessed March 8, 2014).

Summarizing Progress in Global Nuclear Security Governance

The four-year effort has seen the addition of the nuclear security summit process to the global nuclear security framework and significant strengthening of many of the existing elements of the framework: a stronger and more widely accepted IAEA role; strengthened IAEA nuclear security recommendations; modest progress on implementing and strengthening relevant UN Security Council resolutions; more ratifications of key agreements and participation in cooperative initiatives; and more understanding of the threat and more organized interagency focus on nuclear security within particular countries.

Nevertheless, given the potential consequences if the global framework failed in the mission to prevent nuclear terrorism, the framework is still dangerously weak, with no clear standards for how secure nuclear weapons or the materials needed to make them should be; no international organization with authority to do anything but make suggestions and provide help when asked; no clear international forum, once the nuclear security summit process comes to an end, for discussing and deciding on what further steps should be taken; no obvious process for setting standards or goals to be met; and no mechanisms for verifying progress or holding states accountable other than initiatives a few states voluntarily decide to undertake. Clearly there is more to be done.

V. Recommendations

In each of the categories of progress assessed in this report, substantial gaps remain. At The Hague summit and beyond, leaders around the world must commit to taking the steps necessary to close these gaps—to strengthen security measures and rules on the ground; consolidate nuclear weapons and weapons-usable materials in fewer locations; boost security culture, use of best practices, and training; and build a stronger system of global governance of nuclear security.¹⁸⁵ All of this needs to be done with an eye on sustainability over the long haul. And to be effective and sustainable, it all needs to be done with partnership-based approaches that respect the interests of all participants. But none of these steps will be taken—and security culture at sites around the world will not be strengthened—unless policymakers, nuclear managers, and nuclear staff around the world are convinced that nuclear terrorism is a real and urgent threat to their countries’ security, worthy of a significant investment of their time and money, and that improvements on their part are necessary to reduce the risk. Complacency is the enemy of action. There are many other barriers to action, from secrecy to bureaucracy—but if these sets of people are convinced of the urgency of the threat and the need for action to address it, there is a good chance they will succeed in finding ways around the other barriers. Hence, this report’s recommendations begin with steps to overcome complacency.

Combating Complacency

The nuclear security summit process and the Global Initiative to Combat Nuclear Terrorism have both included useful steps to broaden understanding of the threat and build a sense of urgency. Additional needed steps are outlined below.

Shared analyses of incidents and lessons learned. In the world of nuclear safety, when an incident occurs, the plant performs a root cause analysis and develops lessons learned to prevent similar incidents from occurring again. These incident reports and lessons learned are then shared with other reactor operators through organizations such as the World Association of Nuclear Operators (WANO) and national groups such as the US Institute of Nuclear Power Operations (INPO). These organizations can then assess trends among the incidents. INPO not only distributes lessons learned to US reactor operators, it inspects to assess how well reactor operators are implementing the lessons learned.¹⁸⁶ Nothing remotely resembling this approach exists in the security world. It is time to begin such an effort—assessing security-related incidents in

¹⁸⁵ For more recommendations, see William Tobey, “Planning for Success at the 2014 Nuclear Security Summit,” Policy Brief (Muscatine, Iowa: The Stanley Foundation, December 2013), <http://www.stanleyfoundation.org/publications/pab/TobeyPAB1213a.pdf> (accessed March 8, 2014); Matthew Bunn, “Strengthening Global Approaches To Nuclear Security,” Paper presented at the International Conference on Nuclear Security: Enhancing Global Efforts (Vienna: International Atomic Energy Agency, July 1, 2013), http://belfercenter.ksg.harvard.edu/publication/23238/strengthening_global_approaches_to_nuclear_security.html?breadcrumb=%2Fexperts%2F368%2Fmatt_hew_bunn%3Fpage%3D2 (accessed March 8, 2014); and Matthew Bunn et al., *Steps to Prevent Nuclear Terrorism: Recommendations Based on the U.S.-Russia Joint Threat Assessment*, (Cambridge, MA: Belfer Center for Science and International Affairs, Harvard Kennedy School and Institute for U.S. and Canadian Studies, October 2013), http://belfercenter.ksg.harvard.edu/publication/23430/steps_to_prevent_nuclear_terrorism.html?breadcrumb=%2Fpublication%2F23455%2Fnew_report (accessed March 8, 2014).

¹⁸⁶ Joseph V. Rees, *Hostages of Each Other: The Transformation of Nuclear Safety Since Three Mile Island* (Chicago: University of Chicago, 1996).

US Failure to Ratify Key Conventions

A key goal of the four-year effort was to strengthen the global nuclear security architecture—in part by getting as many countries as possible to sign and ratify the key relevant conventions, particularly the 2005 amendment to the Convention on Physical Protection of Nuclear Materials (CPPNM) and the International Convention on the Suppression of Acts of Nuclear Terrorism (ICSANT).¹ But the United States has so far failed to ratify either of these conventions itself, undermining US nuclear security leadership.

The United States first proposed amending the CPPNM in 1998.² The amendment was not completed and opened for signature until 2005—and, as discussed in the main text, it creates no specific standards for security for nuclear materials, enunciating only very broad principles. Nevertheless, the Bush administration signed the amendment and pushed for Senate approval, and the Senate gave its advice and consent to ratification in 2008. Similarly, ICSANT, first proposed by Russia, was also opened for signature in 2005 and approved by the Senate in 2008.

Both of these conventions require parties to criminalize acts related to nuclear terrorism, such as theft of nuclear material or sabotage of a nuclear reactor. Arguably, the relevant acts are already illegal under US laws, but some are not specified in US laws precisely as they appear in the conventions, and both the Bush administration and the Obama administration concluded that implementing legislation was needed to conform US laws to these treaties' requirements. Both administrations decided that they would not deposit instruments of ratification for these conventions until that legislation had been passed into law.

While the Bush administration secured Senate advice and consent to ratification of these treaties, it fell to the Obama administration to propose implementing legislation. The Obama administration hoped to get the legislation approved before the first nuclear security summit in 2010—but Congress failed to act. With the 2010 summit work plan calling for participants to push for universal adherence to these conventions, the administration then tried to get the legislation approved in time for the second nuclear security summit in Seoul in 2012—and Congress once again took no action. The Seoul nuclear security summit called on states to accelerate their ratification efforts, with the goal of bringing the CPPNM amendment into force by 2014. But as of this writing, it appears the United States will again be unable to ratify before the 2014 nuclear security summit.

¹ In the US legislative process, ICSANT is referred to as the Nuclear Terrorism Convention (NTC).

² Secretary of State Madeleine Albright, "Remarks to the Stimson Center," June 10, 1998. One of the authors (Bunn) suggested that the speech propose an amendment to the convention.

depth, exploring lessons learned, and distributing as much of this information among nuclear security operators as necessary secrecy will allow. Non-nuclear incidents that reveal types of tactics against which nuclear materials and facilities should also be included. Information about incidents and how to protect against them could be a major driver of nuclear security improvement, as it has been in safety; in a recent survey of nuclear security experts in 18 countries with weapons-usable nuclear material, incidents were cited far more often than any other factor as a dominant or very important driver of countries' recent changes in nuclear security policies.¹⁸⁷ States could begin with internal assessments of events within their territory, and then provide as much information as can reasonably be exchanged to an international collection of information. The public reports the United States has published on the Y-12 incident and the inadvertent flight

¹⁸⁷ Bunn and Harrell, *Threat Perceptions and Drivers of Change in Nuclear Security*.

US Failure to Ratify Key Conventions (Cont.)

The problem appears to be a combination of lack of sustained high-level attention by both the administration and Congress and disputes over unrelated issues, including the death penalty.³ The original legislation—which would also implement counter-terrorism provisions of recent maritime conventions—included provisions imposing the death penalty for some nuclear terrorism crimes and authorizing wiretapping in some circumstances to prevent them, which some Democrats (including Senate Judiciary Committee Chairman Sen. Patrick Leahy) opposed; some Republicans (particularly Judiciary Committee ranking minority member Sen. Charles Grassley) put a hold on a version that did not include these provisions; and while the House has twice approved a bipartisan compromise (most recently by a vote of 390-3), Leahy and Grassley have been unable to resolve their differences and the Senate has resolutely failed to act.⁴

The US failure to ratify has made it far harder for the United States to pressure other states to ratify and undermined US nuclear security leadership.⁵ The Obama administration and the US Senate need to prioritize ratifying these treaties; once the United States ratifies these agreements, it is likely that enough other countries will follow suit to finally bring the amendment to the CPPNM protection convention into force—years after that should have happened.

³ There has been sustained attention to this issue from officials on the National Security Council staff, but senior administration officials have made only intermittent efforts to weigh in on Capitol Hill, in contrast to the intense administration efforts on many other pieces of legislation.

⁴ See, for example, Miles Pomper and Kingston Reif, “US Delay on Anti-Nuclear Terror Measures Hinders Global Efforts,” *World Politics Review*, May 17, 2013, <http://www.worldpoliticsreview.com/articles/12958/u-s-delay-on-anti-nuclear-terror-measures-hinders-global-efforts> (accessed March 8, 2014); and Sam Kane and Kingston Reif, “Fact Sheet: The 2005 Amendment to the Convention on the Physical Protection of Nuclear Material (CPPNM) and the International Convention on the Suppression of Acts of Nuclear Terrorism” (Washington, D.C.: Center for Arms Control and Nonproliferation, June 13, 2013), http://armscontrolcenter.org/issues/nuclearterrorism/articles/fact_sheet_the_2005_amendment_to_the_convention_on_the_physical_protection_of_nuclear_material_cppnm_and_the_international_convention_on_the_suppression_of_acts_of_nuclear_terrorism_icsant/ (accessed March 8, 2014).

⁵ For a Republican perspective on this point, see Christopher Ford, “U.S. Leadership and Security Against Nuclear Terrorism,” remarks to the workshop on “Combating Nuclear Terrorism: Overcoming the Senate Impasse,” Hudson Institute, November 13, 2012, <http://www.newparadigmsforum.com/NPFtestsite/?p=1487> (accessed March 8, 2014).

of six nuclear weapons across the country are good beginnings—though even there, there is more to be done in describing clearly the root causes of what happened, the lessons other operators should draw, and the actions taken to correct the issues and prevent recurrences.¹⁸⁸

Threat reports and briefings. States that believe they have information on the nuclear terrorist threat should prepare reports and briefings that can be distributed to other states. The United

¹⁸⁸ See, for example, Office of the Inspector General US Department of Energy, *Inquiry Into the Security Breach at the National Nuclear Security Administration's Y-12 National Security Complex*, DOE/IG-0868 (Washington, D.C.: DOE, August, 2012); http://energy.gov/sites/prod/files/IG-0868_0.pdf; Defense Science Board Permanent Task Force on Nuclear Weapons Surety, *Report on the Unauthorized Movement of Nuclear Weapons* (Washington, D.C.: US Department of Defense, February, 2008); http://www.fas.org/nuke/guide/usa/doctrine/usaf/Minot_DSB-0208.pdf (accessed March 8, 2014).

States, in particular, should prepare a detailed report on what it knows about how easy or difficult it would be for a sophisticated terrorist group to make a crude nuclear bomb; past efforts by al Qaeda and other terrorist groups to get nuclear bombs; the potential for terrorists to be able to get plutonium or HEU from nuclear thieves and smugglers; and other elements of the nuclear terrorist threat. Different versions should be prepared for public distribution and for confidential exchange among states.

Discussions among intelligence agencies. Most states rely on their intelligence agencies to provide information on the threats their countries face. Hence, a series of discussions among intelligence agencies to share information on the nuclear terrorist threat would be very valuable. Such discussions could also lead to expanded intelligence cooperation to deal with nuclear smuggling and nuclear terrorist activities.

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, exploring scenarios of nuclear theft and terrorist detonation of a nuclear bomb. As noted earlier, the Hague summit will take an important step in this direction, with leaders participating in an unfolding nuclear terrorism scenario. A program of such exercises should become a central element of the Global Initiative.¹⁸⁹

The “Armageddon Test.” President Obama should direct US intelligence—preferably working in cooperation with agencies in other countries—to establish a small operational team dedicated to understanding and penetrating the world of nuclear theft and smuggling. They would seek to answer the outstanding questions from past cases—where the material came from, who stole it and how, what smugglers were involved, whether there were real buyers, how buyers and smugglers connected with each other, and more. They would probe to see who is in the market today. In some cases they might pose as either potential buyers or potential sellers of nuclear material, although they should do nothing to simulate a demand for material that might make its theft more likely. In other cases, they might offer substantial sums for information leading to the capture of nuclear smugglers and the nuclear material in their possession. If they succeeded in making contact with smugglers who had access to weapons-usable material, this would dramatically highlight the continuing threat, and potentially identify particular weak points and smuggling organizations requiring urgent action. If they failed, that would suggest that terrorist operatives would likely fail as well, building confidence that measures to prevent nuclear terrorism were working.¹⁹⁰

Improving Protection for Facilities and Transports

Protection against the full spectrum of plausible threats. Countries should establish and sustain security measures that will protect nuclear weapons, weapons-usable material, and major nuclear facilities against the full spectrum of adversaries their intelligence agencies judge to be credible threats—including both outsiders and insiders. As argued earlier, all nuclear weapons

¹⁸⁹ For example, GICNT and the NNSA Second Line of Defense program organized an exercise for working-level officials exploring a scenario at the port of Manzanillo, Mexico in February 2014. Information provided by NNSA, March 2014.

¹⁹⁰ William Tobey and Rolf Mowatt-Larssen, “The Armageddon Test: To Prevent Nuclear Terrorism, Follow the Uranium,” Belfer Center for Science and International Affairs (July 26, 2010), http://live.belfercenter.org/publication/20279/armageddon_test.html (accessed March 8, 2014).

and weapons-usable nuclear material everywhere should at least be protected against a baseline threat that includes a well-placed insider; a modest group of well-trained and well-armed outsiders, capable of operating as more than one team; and both an insider and the outsiders working together.¹⁹¹ A broad range of possible adversary tactics should be included in the protection requirement. Prescriptive rules will still be needed—as they are in safety—but they should increasingly be supplemented with performance-based approaches.

Effective regulation. As noted earlier, strong nuclear security and accounting rules, well-enforced, are critical to effective and sustainable nuclear security. States with nuclear or radiological stocks and facilities to protect should ensure that their regulators have the independence, resources, expertise, and culture to do their jobs effectively. As the United States has found, it can be expensive to comply with effective nuclear security regulations for nuclear weapons, plutonium, or HEU—and this helps motivate nuclear managers to eliminate these materials wherever possible, thus contributing both to consolidation and to ensuring effective security wherever stocks remain. Strengthening nuclear security regulation should be a key focus of international nuclear security cooperation and best practice exchanges. Regulators should expand their efforts to meet, exchange best practices, develop model regulations where appropriate, and work cooperatively to strengthen nuclear security regulation, internationally, regionally, bilaterally, and through organizations such as the IAEA.¹⁹²

Security culture, training, and use of best practices. Recommendations on these issues are discussed in a separate section below; steps in these areas are fundamental to achieving effective and lasting nuclear security for facilities and transporters around the world.

Better protection against insider threats. All of the thefts of HEU or plutonium where the circumstances are known appear to have been perpetrated by insiders or with the help of insiders. Protecting against insiders who have authorized access to the material, are trusted by the other staff, and may be well informed about the weaknesses of the security measures in place is particularly challenging. States with nuclear weapons, plutonium, or HEU should put in place comprehensive insider protection programs, combining effective screening and monitoring of personnel; storage of all material in secure vaults whenever it is not in use; strong material controls that ensure that material is monitored at all times and any removal would be rapidly detected; two-person or three-person rule, to ensure that no one is ever alone with a nuclear weapon or weapons-usable nuclear material; accounting of nuclear material that is accurate and timely enough to notice either a rapid or a protracted theft and help identify where the loss is occurring and who might have had access; portal monitors at all potential entrances and exits to set off an alarm if any material is being removed; and regular tests, assessments, and inspections to ensure the effectiveness of the insider protection program in place.¹⁹³

¹⁹¹ Matthew Bunn and Evgeniy P. Maslin, “All Stocks of Weapons-Usable Nuclear Materials Worldwide Must be Protected Against Global Terrorist Threats,” *Journal of Nuclear Materials Management*, Vol. 39, No. 2 (Winter 2011), pp. 21-27.

¹⁹² The “International Regulators Conference on Nuclear Security” sponsored by the US Nuclear Regulatory Commission in 2012 is a useful example, as is the more in-depth work of the European Nuclear Security Regulators Association (ENSRA), and the still more in-depth bilateral cooperation that has taken place, for example, between the United States and Russia. For more on ENSRA, see Hans Mattli, “European Nuclear Security Regulators Association,” presentation to “Nuclear Power in the 21st Century,” St. Petersburg, Russia, June 2013, <http://www-pub.iaea.org/iaeameetings/cn206p/Session2-ENSRA.pdf> (accessed March 8, 2013).

¹⁹³ World Institute for Nuclear Security, *Managing Internal Threats: A WINS International Best Practice Guide for*

Improved security for bulk processing facilities. When nuclear material is being processed in bulk, it is far easier for insiders to steal small amounts at a time without anyone noticing. Nearly all of the seizures of stolen HEU and separated plutonium that have occurred have been of bulk material such as powders, apparently stolen without detection by insiders from bulk processing facilities such as fuel fabrication plants. All countries operating such facilities need to work harder to ensure that every practical measure has been taken to control and account for these materials and reduce the chances of theft. The United States and Russia, in particular, should jointly review the accounting and control measures they have implemented at bulk processing facilities, identify potential improvements, and implement them.¹⁹⁴

Sufficient resources. States should act to ensure that all of the national and international organizations who play major roles in providing effective nuclear security have the resources needed to do their jobs—including money, trained personnel, and units focused on the nuclear security mission. Some facilities with modest revenues may require state support to provide effective security. If the costs of effective security for weapons-usable nuclear material are more than keeping the material at a site is worth, the material should be removed. In cases where sites or transporters have been receiving US or other help with some nuclear security costs, that help should only be phased out after a plan for funding the needed work from other sources has been put in place and there is good confidence it will be implemented successfully.

Sustainability. It is not enough for effective nuclear security to be achieved at one particular moment; nuclear security must be maintained and continually improved for decades to come. Sustaining nuclear security requires both capacity and political commitment; assistance programs should focus not only on capacity-building but on the difficult task of commitment-building, convincing the state that it is in its interest to take the actions needed to sustain effective security for the long haul. As noted earlier, effective regulation is particularly important to sustainable security. The United States and Russia, in particular, should work out a partnership-based approach to continuing cooperation that ensures that the substantial investments both countries have made in improved security measures are sustained for the future. The IAEA should expand its emphasis on sustainability in providing nuclear security assistance, as it is beginning to do in its Technical Cooperation program more generally.

Realistic testing of security performance. Realistic tests, in which groups pretending to be adversaries attempt to find ways to defeat the security at a site, can be crucial in identifying vulnerabilities, training guard forces and convincing them of the danger that adversaries could overcome their security systems, and convincing policymakers of the need for action to improve nuclear security.¹⁹⁵ In the US experience, many security systems that looked good on paper failed

Your Organization, Rev. 1.0 (Vienna: WINS, 2010); International Atomic Energy Agency, *Preventive and Protective Measures Against Insider Threats*, IAEA Nuclear Security Series No. 8 (Vienna: IAEA, 2008). See also Matthew Bunn and Kathryn M. Glynn, “Preventing Insider Theft: Lessons from the Casino and Pharmaceutical Industries,” *Journal of Nuclear Materials Management* Vol. 41 No. 3 (Spring 2013): pp. 4-16, and Matthew Bunn and Scott Sagan, “A Worst Practices Guide to Insider Threats: Lessons From Past Mistakes” (Cambridge, Mass.: American Academy of Arts and Sciences, March 2014).

¹⁹⁴ As just one example, expanded use of process monitoring could improve accounting systems’ ability to detect removals rapidly.

¹⁹⁵ World Institute for Nuclear Security, *Guard Force Training and Motivation*, WINS International Best Practice Guide Revision 1.0 (June 2011).

to provide effective protection in the face of determined and intelligent adversaries looking for their weak points. The IAEA now recommends that states conduct such force-on-force exercises, but only a minority of states do so regularly or realistically.¹⁹⁶ States with nuclear weapons, HEU, separated plutonium, or major nuclear facilities should implement regular, realistic force-on-force exercises to test operators' ability to protect against the DBT. States should also work to develop approaches to testing and assessing protection against insider threats that are as realistic as practicable. The United States and other donors should work with states to help them put realistic testing programs in place.

Accepting independent reviews. Review and advice from experts outside the group that designed and is implementing a nuclear security system can often be extremely helpful in finding areas for improvement. Beyond inspections by regulators, independent peer reviews by experts from other plants have become a regular part of strengthening nuclear safety all over the world. Within the necessary confines of secrecy, states should take a similar approach with nuclear security. In particular, states should request IPPAS missions to review security for their civilian infrastructure; many states, whether developed or developing countries, have found that these missions provide substantial benefit in improving their nuclear security approaches. States with military nuclear activities should work to develop peer review approaches for such activities—beginning with reviews by other operators within their own country and secrecy system.

Consolidating Stockpiles

A more far-reaching consolidation effort. Current programs to minimize civilian use of HEU are making progress and deserve strong support and robust funding. They should be expanded with the goal of phasing out the civilian use of HEU and eliminating stocks of HEU at civilian sites. In particular, the US GTRI program should expand its consolidation efforts to include the HEU it has identified as potential targets for consolidation in its recent HEU reconciliation study, and should discuss with countries what should be done with all other stocks of civilian HEU. The United States and other countries should undertake new efforts to consolidate civilian separated plutonium and limit the buildup of ever-larger stockpiles. At the same time, the United States, Russia, and other interested countries should expand cooperative efforts to consolidate military stocks of nuclear weapons, separated plutonium, and HEU as well.¹⁹⁷

Reviews of the costs, risks, and benefits of each site. Each state with nuclear weapons, HEU, or separated plutonium should undertake a review of each site where these materials exist, eliminating any site whose continued benefits are outweighed by its costs and risks. The material should then be consolidated at other sites.

National consolidation plans. Russia and the United States, in particular, as the countries whose nuclear stockpiles are dispersed at the largest number of buildings and bunkers with nuclear weapons or weapons-usable material, should each develop a national-level plan for accomplish-

¹⁹⁶ International Atomic Energy Agency, *Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities*, INFCIRC/225/Rev.5 (Vienna: IAEA, 2011), http://www-pub.iaea.org/MTCD/publications/PDF/Pub1481_web.pdf (accessed March 8, 2014).

¹⁹⁷ For more detailed analysis and recommendations, see Matthew Bunn and Eben Harrell, *Consolidation: Thwarting Nuclear Theft* (Cambridge, Mass.: Project on Managing the Atom, Harvard University, March, 2012), http://www.nuclearsummit.org/files/Consolidation_Thwarting_Nuclear_Theft.pdf (accessed March 8, 2014).

A New Approach to US-Russian Nuclear Security Cooperation

Given the crisis in Ukraine, there is no near-term prospect for new initiatives to strengthen US-Russian nuclear security cooperation. As political tensions flare, simply maintaining the cooperation already underway will require strong leadership.

But it must be remembered that investing in nuclear security is not something the United States ever did as a favor to Russia—it was and remains a direct investment in reducing dangerous threats to US national security. Cooperating with the United States was never something Russia did as a favor to the United States—it was a choice focused on strengthening Russian national security. Even during the height of the Cold War, as they were locked in a global competition, the United States and the Soviet Union worked together to build the nuclear nonproliferation regime and limit strategic nuclear arms—because doing so served their national security interests.

No one should lose sight of those interests in the swirl of tensions over the crisis in Ukraine, or any situation that might develop thereafter. Nuclear security cooperation must continue—just as it did through the war in Georgia in 2008. And if the current crisis is resolved peacefully and the United States and Russia manage to return to cooperating where doing so serves the national interests of both, there is room for a new initiative, to build a stronger, more equal approach to nuclear security cooperation.

The days of large-scale installation of new equipment for nuclear material protection, control, and accounting (MPC&A) in Russia are nearly over. The work of that kind that the two sides agreed to do is almost completed, and the Russian government now rejects any notion that Russia is weak and needs assistance.

But there remains a compelling need for a new approach to US-Russian nuclear security cooperation, based on working together to achieve common interests, with ideas and resources coming from both sides.¹ The United States and Russia have by far the world's largest nuclear stockpiles and the largest nuclear complexes. Indeed, together they possess over 90% of the world's nuclear weapons, over 90% of the world's HEU, and more than half of the world's separated plutonium. As a result, they have more experience with security and accounting for nuclear weapons and materials than any other countries. Both countries have also been targets for highly capable terrorist groups seeking the ability to launch nuclear or radiological attacks.²

Yet, both countries continue to face serious nuclear security challenges. (These are described in the text in Russia's case, and highlighted by the intrusion at Y-12 and a host of other incidents and issues in the US case, elsewhere in the report). Both can benefit from learning from the other's experience in addressing these challenges. Hence, Russia and the United States should undertake an ongoing, long-term nuclear security cooperation effort, focused on helping other countries improve their nuclear security and on exchanging ideas, visits, and technologies to make further improvements in their own nuclear security arrangements.

In particular, as discussed in the main text, the United States and Russia should each commit to protect all their stocks of nuclear weapons, HEU, and separated plutonium against the full range of plausible outsider and insider threats – with a set of particular steps to achieve that objective – jointly lead a global effort to convince other countries where such stocks exist to join in this commitment by the time of the last nuclear security summit in 2016.

More broadly, a new, long-term nuclear security cooperation effort should include:

- Working together to help other countries improve nuclear security, prioritizing the most important risks of nuclear theft, sabotage, and smuggling to be reduced.

¹ For earlier discussions of such a partnership-based approach, see US National Research Council, Committee on Strengthening and Expanding the Department of Defense Cooperative Threat Reduction Program, *Global Security Engagement: A New Model for Cooperative Threat Reduction* (Washington, D.C.: National Academy Press, 2009); http://www.nap.edu/openbook.php?record_id=12583; Oleg Bukharin, Matthew Bunn, and Kenneth N. Luongo, *Renewing the Partnership: Recommendations for Accelerated Action to Secure Nuclear Material in the Former Soviet Union* (Washington, D.C.: Russian American Nuclear Security Advisory Council, 2000); <http://belfercenter.ksg.harvard.edu/files/mpca2000.pdf>; For recent joint US-Russian recommendations on a broader joint effort to prevent nuclear terrorism, see Matthew Bunn, Valentin Kuznetsov, Martin B. Malin, Yuri Morozov, Simon Saradzhyan, William H. Tobey, Viktor I. Yesin, and Pavel S. Zolotarev, *Steps to Prevent Nuclear Terrorism: Recommendations Based on the U.S.-Russia Joint Threat Assessment* (Cambridge, Mass.: Belfer Center for Science and International Affairs, Harvard Kennedy School, and Institute for U.S. and Canadian Studies, October 2013).

² Bunn et al., *U.S.-Russia Joint Threat Assessment*.

A New Approach to US-Russian Nuclear Security Cooperation (Cont.)

- Regular workshops to exchange ideas about how best to address problems that both sides face—such as maintaining strong security cultures, coping with insider threats, achieving effective security efficiently, assessing and testing the performance of nuclear security systems, structuring incentives so that individuals, teams, and organizations are motivated to focus on effective security, and more.
- Regular visits to key facilities in each country, to demonstrate and review nuclear security approaches, confirm that nuclear security is being sustained, and exchange best practices. These visits should be reciprocal: when the United States asks for a certain level of access at a sensitive facility in Russia to facilitate the cooperation, it should be prepared to offer similar access at a comparable facility in the United States.³
- Working together to minimize the number of locations where nuclear weapons, HEU, or separated plutonium exist, in order to achieve higher security at lower cost. This would include shipment and disposition of unneeded stocks, building or modifying facilities in which to consolidate storage, converting research reactors (or closing unneeded ones), and more.
- Installation of additional equipment where both parties agree that it is needed.
- Joint development of new and strengthened approaches to regulating MPC&A.
- Expanded training of nuclear security experts, with opportunities for experts from both countries to provide and receive training in both countries, to develop curricula together, and to train together. For example, adversary teams used in testing the performance of nuclear security systems could train together, giving each country a better understanding of how the other country tests to ensure its nuclear security systems are performing at a high level.
- Joint development of new MPC&A technologies and approaches, which could offer more effective security at lower cost.

The recent agreement to extend cooperative threat reduction work under the framework of the Multilateral Nuclear Environmental Program in the Russian Federation (MNEPR) and the Department of Energy's recent science and technology agreement with Rosatom provide a strong foundation for pursuing such a continuing partnership on nuclear security. The United States and Russia should also cooperate to take other steps to reduce the danger of nuclear and radiological terrorism. A focused effort to collect intelligence on potential nuclear terrorist plots is particularly important. Each country should establish an intelligence team focused full-time on collecting and analyzing such information, and these teams should regularly exchange information.⁴

In particular, the United States and Russia should establish a Center for Nuclear Security, located in Moscow, where US and Russian nuclear security and accounting experts would work side by side. This center would work to assess nuclear security issues and problems; identify potential steps to improve nuclear security and propose them to the US and Russian governments; consider obstacles to nuclear security improvements and how they might be overcome; work with other organizations to develop best practice guides and training programs; and tackle such other nuclear security questions as both countries may direct. Such a center would create a group of US and Russian experts with experience working together and an institutional interest in pushing for additional steps to strengthen nuclear security.

This is an ambitious agenda, and overall relations between the United States and Russia are strained. Leadership from the highest levels of government would be necessary to build such a partnership. But such an effort is overwhelmingly in the security interests of both countries, offering reason to hope that such a continued and expanded partnership in nuclear security cooperation can be achieved.

³ It is worth noting that Russian security experts have already visited the Pantex nuclear weapons assembly/disassembly facility; the Los Alamos, Livermore, and Sandia national laboratories; and material production and handling facilities such as Hanford, Savannah River, Rocky Flats (now closed), and Y-12. But a more broadly reciprocal approach would address Russian complaints about unilateral US intrusion in sensitive areas, and impose a discipline on US access requests, if the United States would have to put up with similar inconveniences at its own sites.

⁴ Bunn et al., *Steps to Prevent Nuclear Terrorism*, p. 20.

ing their military and civilian nuclear objectives with the smallest practicable number of locations with nuclear weapons or weapons-usable material. (In the 1990s, Russia's Ministry of Atomic Energy committed to developing a consolidation plan for civilian nuclear material, but this was never accomplished.) The two countries should discuss the specifics of these plans, and ways that cooperative efforts such as the HEU minimization group under the Poneman-Kirienko Nuclear Energy and Security working group can contribute to them.

Consolidation incentives. Facilities using HEU or plutonium are often resistant to change—and in a recent survey of nuclear security experts in 18 countries with plutonium or HEU, experts from 13 countries reported that the nuclear security rules and procedures in their countries either created no significant incentive to consolidate these stocks or gave sites incentives to maintain the stocks they had.¹⁹⁸ The US government and other interested governments should continue and expand their use of substantial packages of incentives, shaped for the needs in each case, to convince countries to eliminate civilian sites with dangerous stocks of high-quality HEU. Donors, for example, could offer financial support for work at other research reactors and help with decommissioning if an HEU-fueled research reactor shuts down, or, if a high-flux research reactor agreed to convert to LEU fuel, donors could offer improved neutron guides that would allow the reactor to achieve a better flux of neutrons during experiments than ever before.¹⁹⁹ States should ensure that their nuclear security regulations are appropriately graded (as recommended in INFCIRC/225) so that operators can achieve substantial savings in annual security costs by eliminating plutonium or HEU, even if they continue to have LEU on-site. States should eliminate any institutional incentives that may exist for operators to maintain HEU or separated plutonium (such as increased research funding for facilities using these materials, for example).

A new effort to encourage HEU-fueled reactors to shut down. Most of the world's research reactors are no longer needed; there are over 250 research reactors in the world (almost half of them fueled with HEU), and IAEA experts have estimated that the world only needs 30–40 such reactors for the long term.²⁰⁰ Many of the HEU-fueled facilities that have the highest-quality material would be quite difficult to convert to LEU, but could have few missions and could be shut down. Shutting down reactors will frequently be cheaper than converting them, and unlike conversion, there are no technical barriers to shut-down. The United States, working with other countries (perhaps through the IAEA) should establish a program to offer incentives for unneeded HEU-fueled facilities to shut down, including assistance with decommissioning costs, funding for scientists to share time at other research reactors in their region, and more.²⁰¹

¹⁹⁸ Bunn and Harrell, *Threat Perceptions and Drivers of Change in Nuclear Security*.

¹⁹⁹ See Alexander Glaser and Uwe Filges, “Neutron-Use Optimization with Virtual Experiments to Facilitate Research Reactor Conversion to Low-Enriched Fuel,” *Science & Global Security*, Vol. 20, No. 2–3 (2012), pp. 141-154.

²⁰⁰ International Atomic Energy Agency, “New Life for Research Reactors? Bright Future but Far Fewer Projected” (Vienna: IAEA, March 8, 2004), <http://www.iaea.org/NewsCenter/Features/ResearchReactors/reactors20040308.html> (accessed March 8, 2014).

²⁰¹ Bunn and Harrell, *Consolidation*, pp. 38–40.

Strengthening Security Culture, Best Practices, and Training

Building organizational cultures in which all staff members take security seriously and are continuously on the lookout for vulnerabilities that should be fixed is crucial to effective and sustainable nuclear security. Sharing and implementing nuclear security best practices—through the World Institute for Nuclear Security and other forums—is also crucial, as is providing the training needed for everyone from managers to guards to do their jobs effectively.

Targeted security culture assessment and improvement programs. All states with nuclear weapons, HEU, separated plutonium, or major nuclear facilities should ensure that each operator dealing with these items or facilities has a program in place to assess and strengthen its security culture, and is participating in best-practice exchanges. These programs can make use of published guidance from WINS and the IAEA.²⁰² Belief in the threat is a central element of a strong security culture; in addition to the steps to counter complacency suggested above, states should provide detailed threat briefings for nuclear managers and key security-related staff, as well as engaging them in exercises of scenarios related to nuclear theft and terrorism.

Incentives for nuclear security. States should ensure that nuclear operators have incentives not only to comply with rules but to achieve excellent nuclear security performance. Operators should also structure incentives to motivate key staff to take security seriously and invest their time and effort in finding and fixing vulnerabilities and suggesting improvements.²⁰³ What organizations reward sends a powerful signal to employees about management’s real priorities are.

Exchanges of best practices. All operators handling nuclear weapons, HEU, or separated plutonium, or managing major nuclear facilities or dangerous radiological sources, should join WINS, participate in its best practice exchanges, and help to support it financially where practicable. States should encourage their operators to participate, and should contribute financially to WINS. States should also pursue additional channels for best-practice exchanges, such as those the United States, Russia, and the United Kingdom have been undertaking in recent years.

Targeted, high-quality training. States should assess what specific training is required for each nuclear-security-related job at their nuclear facilities—with help from the IAEA and others if needed—and establish training programs to ensure that the necessary training is provided. The many training programs now being established should rely as much as possible on experts with substantial experience in nuclear security, and provide training focused on the highest-priority needs for trained personnel. Training programs should request reviews of the quality and suitability of the training they are providing. Over time, states should move toward a model similar to the one that exists in nuclear safety, in which regulators require that people and companies undertaking certain roles have certified competence to do so.

²⁰² International Atomic Energy Agency, “Nuclear Security Culture: Implementing Guide,” World Institute for Nuclear Security, *Nuclear Security Culture: A WINS Best Practice Guide for Your Organization*.

²⁰³ Matthew Bunn, “Incentives for Nuclear Security,” *Proceedings of the 46th Annual Meeting of the Institute for Nuclear Materials Management*, Phoenix, Arizona, July 10–14, 2005 (Northbrook, Ill.: INMM, 2005), <http://belfer-center.ksg.harvard.edu/files/inmm-incentives2-05.pdf> (accessed March 8, 2014).

Building a More Effective Global Nuclear Security Framework

The world needs a stronger global nuclear security framework, a structure that helps states cooperate to establish standards and goals for nuclear security; discuss and decide on next steps to improve nuclear security; confirm that states are fulfilling their responsibility to provide effective security; and track states' progress in fulfilling their nuclear security commitments. Such a strengthened framework could include several elements. The first step, of course, would be to get states to ratify and implement the existing conventions, carry out the existing recommendations, and participate in the voluntary initiatives already in place, but more needs to be done as well.

Political commitments to achieve a “baseline” level of nuclear security. Past experience suggests that negotiating treaties takes too long and results in too few specific requirements to be an effective pathway for achieving strong standards for nuclear security. Political commitments made by groups of like-minded states may work better. The United States and Russia, joined by as many other states as are willing, should make a political commitment to require facility operators and transporters to protect nuclear weapons, weapons-usable nuclear materials, and major nuclear facilities against the full range of outsider and insider threats that their intelligence and nuclear agencies judge to be credible—including, at a minimum, the baseline DBT described above. Such a commitment should also include a range of specific steps to fulfill that objective, from having well-armed, well-trained on-site response forces to putting in place material control and accounting systems adequate to detect either abrupt or protracted thefts and determine roughly where and when the loss occurred. The participating states should invite others to join them in their commitment to high standards of nuclear security, and offer assistance to those who might like to make the commitment but need help to do so. The participating group should meet regularly to review progress and outline additional steps that might be taken. Such a joint commitment to high standards of nuclear security could be a key “gift basket” for the 2016 nuclear security summit.

Sustained, partnership-based nuclear security cooperation. Largely beginning with the Nunn-Lugar initiative, technical cooperation to upgrade nuclear security has been one of the most important and successful elements of the global nuclear security framework. The United States and other countries should sustain these efforts, building them on a genuinely partnership-based approach. As argued earlier, nuclear security cooperation with Russia in particular should be continued, which calls for such a new approach. Continued US-Pakistani cooperation is also needed. Political disputes should not be allowed to derail cooperation that serves the interests of all parties in lowering the risk of nuclear and radiological terrorism.

Ratifying and implementing existing treaties. States should ratify the physical protection convention, its 2005 amendment, and the nuclear terrorism convention. The United States, in particular, should move to ratify these treaties before the end of 2014, and seek to convince other countries to do likewise. States should pledge to implement the nuclear terrorism convention and the amendment to the physical protection convention provisionally, even before their ratifications become effective and the amendment enters into force.

Actions to strengthen the IAEA's nuclear security role. States should take action to strengthen the IAEA's role in nuclear security, providing it with additional political support, direction, and

resources. In particular, states should provide robust funding for the Division of Nuclear Security, with a substantial portion of the needed funds coming from the regular IAEA budget, to ease planning and prioritization.²⁰⁴ (As noted above, states should also provide robust funding for WINS.)

Steps to build confidence that effective nuclear security is in place. The Y-12 incident—in which NNSA headquarters had no idea the Y-12 site had developed such significant problems until the incident occurred—raises difficult questions about how states could assure others that they are providing effective security when they may not even know for sure themselves. Still, there are many steps states can and should take to improve confidence. These include:

- **Publishing information.** States should regularly publish information about their nuclear security requirements and approaches and the means they use to assure effective performance (including how they test and inspect nuclear security systems). Organizations such as WINS could develop guides to help states and organizations report such information in a common format, if they chose to use them. (The United States, for example, publishes detailed information on how its force-on-force exercises are conducted and how many of its facilities did well in these tests; on occasion, it also hosts foreign observers of these exercises.) One possibility would be for countries to voluntarily prepare reports at regular intervals on what they are doing to improve nuclear security, which could be discussed at international meetings open to all participating states; although voluntary and not treaty-based, this approach would be similar in broad terms to what is already done for nuclear safety under the terms of the Convention on Nuclear Safety. Another approach would be for the IAEA to establish a Nuclear Security Register on its website for states to voluntarily register their achievements (along the lines of the Agency’s Nuclear Safety Dashboard and the UN’s Arms Trade Register).²⁰⁵
- **Publishing more detailed UNSCR 1540 reports.** States should include detailed information on their nuclear security rules and practices in their UNSCR 1540 reports, to build confidence that their nuclear security, physical protection, and nuclear accounting arrangements really are appropriate and effective as required. Donor states and international organizations should provide assistance in drafting these detailed reports to states with limited capacity; indeed, it might be desirable to establish one or more commercial firms that could assist states in preparing these reports. Here, too, WINS could provide guides that would suggest a common format and categories of information that might be included.
- **Inviting international review.** States should regularly request IPPAS missions from the IAEA, including reviews of large and sensitive nuclear facilities where these exist. All IPPAS host states should publish unclassified summaries of the results of such international peer reviews, and the steps they are taking to address them.
- **Alternative measures for sensitive stocks.** States with particularly sensitive nuclear operations that are not likely to receive IPPAS missions soon, including military nuclear opera-

²⁰⁴ Trevor Findlay, *Beyond Summitry: The Role of the IAEA in Nuclear Security Diplomacy after 2016* (Cambridge, Mass: Project on Managing the Atom, Harvard University, March 2014), <http://belfercenter.ksg.harvard.edu/publication/23986>; see also Trevor Findlay, *Unleashing the Nuclear Watchdog: Strengthening and Reform of the IAEA* (Waterloo: ON: Centre for International Governance Innovation, April 2013) and 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), pp. 21–23.

²⁰⁵ Findlay, *Beyond Summitry*.

A Multi-Layered Defense Against Nuclear Terrorism

Nuclear security systems will never be perfect—and some nuclear material may already have been stolen and never recovered. Hence, a multilayered effort to block the terrorist pathway to the bomb is needed, with nuclear security as the first and most important layer.¹ The United States and other countries seeking to reduce this risk should expand police and intelligence cooperation focused on identifying and countering terrorist groups with nuclear ambitions and seeking to interdict nuclear smuggling. They should work to ensure that countries around the world have criminal laws in place imposing heavy penalties for any participation in efforts to steal or smuggle nuclear material or granting any assistance to nuclear terrorists—and that states have units of their national police trained and equipped to deal with such cases. They should create new tip lines and reward programs to encourage participants in such conspiracies to blow the whistle. While the likelihood that hostile states would consciously decide to transfer nuclear weapons or the materials needed to make them to terrorists is already low, the United States and its international partners should seek to lower it further, in particular by putting together international packages of incentives and disincentives large enough and credible enough to convince North Korea that it is in its national interest to cap its nuclear program and not to transfer nuclear technologies to others and to convince Iran that it is in its national interests to agree to restraints that would maintain a significant and verifiable barrier between Iran’s program and nuclear weapons. The United States should also make crystal clear the consequences that any state found to have intentionally transferred such items to terrorists would face.

Fortunately, many steps along these lines are already being taken, though there is more still to be done. The killing of Osama bin Laden and the many other blows against al Qaeda have reduced the risk that al Qaeda could put together and carry through a nuclear bomb project. But al Qaeda has proved resilient in the past. And as noted elsewhere in this report, other terrorist groups have pursued nuclear weapons in the past and may do so in the future.²

At the same time, many countries are also strengthening their ability to deter and interdict nuclear smuggling. Following up on UN Security Council Resolution 1540, a number of countries have put in place stronger criminal laws imposing severe penalties for crimes related to nuclear theft, smuggling,

¹ For a list of the steps along a terrorist pathway to the bomb, and recommendations for the steps beyond improved nuclear security, see Mathew Bunn, *Securing the Bomb* 2010, p. 8 and pp. 106–109.

² For a discussion of al Qaeda, see Bruce Hoffman, “Al Qaeda’s Uncertain Future,” *Studies in Conflict & Terrorism*, Vol. 36, No. 8, pp. 635–653.

tions, should work together to establish ways to build confidence that they are meeting their nuclear security obligations without compromising necessary secrecy. One approach, for example, would be to exchange detailed information on the kinds of security tests and assessments they perform—perhaps extending to the level of having the adversary teams that perform such tests train together—and then exchange information on the general results of such exercises (such as the fraction of facilities that met certain levels of performance).

Continuing the Dialogue Beyond the Nuclear Security Summits

Although countries have agreed to another nuclear security summit in 2016, it is likely that this will be the last. Several forums might be able to take on parts of the function that the nuclear security summits have played.

A Multi-Layered Defense Against Nuclear Terrorism (Cont.)

and terrorism. The United States, Interpol, and others are working with a number of countries to establish national units trained and equipped to investigate nuclear smuggling networks. Many countries have installed radiation detectors at key ports, airports, and border crossings, often with US help and financing. Interpol, the world police organization, has set up a small group focused on nuclear, chemical, biological, and radiological crimes, and announced in 2011 that it was establishing a new Radiological and Nuclear Terrorism Prevention Unit.³

Unfortunately, however, the huge length of key borders, the immense legitimate traffic across them, the deeply entrenched smuggling of many other types of contraband that takes place worldwide, the corruption of some border officials, and the small size of the materials needed for a bomb conspire to make intercepting nuclear smuggling an enormous challenge. Uranium and plutonium, while radioactive, are not so radioactive as to make them difficult to carry or easy to detect. Most of the detectors that have been installed around the world would have a good chance of detecting plutonium or gamma-emitting radiological sources, but would not be likely to detect well-shielded HEU.

Moreover, the news on interdicting nuclear smuggling has not all been positive. Genuine cooperation between intelligence agencies of different countries—particularly between Russia and the United States—on the nuclear smuggling threat remains scarce. Russia and the United States worked together to complete the installation of radiation detectors at all of Russia’s official border crossings, but with the new customs union with Kazakhstan and Belarus, many of these border crossings have become effectively irrelevant, pushing the real border out to the edges of Kazakhstan and Belarus, and not all of their border crossings yet have radiation detectors. The Obama administration is working to plug those gaps, and has shifted its radiation detection strategy to supplement fixed detectors that smugglers might notice and circumvent with mobile detectors targeted for internal law enforcement. But the pace of progress remains modest. Radiation detection is only one of many tools for reducing the risk of nuclear terrorism, and not the most effective one—but at sites where there is good reason to believe nuclear smuggling is a real risk, the geography suggests it would be difficult for smugglers to go around the official border crossing, and there is reason to believe the detectors will be used effectively and sustained, it is worthwhile to move rapidly to help countries put effective radiation detection in place.

³ “Interpol Creates Nuclear Terrorism Prevention Unit,” *Security and Defense Agenda*, May 19, 2011, <http://www.securitydefenceagenda.org/Contentnavigation/Library/Libraryoverview/tabid/1299/articleType/ArticleView/articleId/2577/Interpol-creates-nuclear-terrorism-prevention-unit.aspx> (accessed March 8, 2014).

IAEA nuclear security meetings. At its July 2013 nuclear security conference, the IAEA included a ministerial gathering for the first time. The IAEA plans to hold such meetings every three years, to assist in drafting its nuclear security plans. With all member states invited, such IAEA gatherings have considerable political legitimacy. With the combination of ministers and technical experts, these meetings provide an opportunity for both technical dialogue and political decisions—particularly if, in future, the ministerial meeting is structured as a working meeting intended to reach decisions on particular actions rather than the series of five-minute speeches featured at the July 2013 meeting. The process for preparing for the conference could perhaps be structured to prepare the ground for such a discussion.

“Friends of Nuclear Security.” The United States has proposed that interested states work together to develop proposals to strengthen the IAEA’s role and the international nuclear security

framework. By allowing proposals to be discussed and developed in what would likely be a like-minded group of relatively modest size, this could increase the efficiency of concept development—and those ideas could then be addressed by the full IAEA membership.

Review meetings for the Convention on Physical Protection. The CPPNM contains a provision for review conferences on the request of a majority of the parties, at intervals of “not less than five years.” No such conference has been held for over 30 years. If enough states could be persuaded to call for such a conference, this could provide another venue for discussing next steps to strengthen nuclear security—and perhaps for discussion of voluntarily submitted national reports on nuclear security progress, as suggested earlier. Such review conferences could be held back-to-back with the IAEA nuclear security meetings, strengthening the impact of each.

An expanded Global Initiative. To date, the Global Initiative to Combat Nuclear Terrorism has focused primarily on aspects of preventing nuclear terrorism other than security for nuclear weapons, weapons-usable materials, and major nuclear facilities. The participants could create an additional element of the Global Initiative focused specifically on improving security for these items and facilities, working out commitments to high standards, exchanging best practices, working with states to help put particular security measures in place, and more. Plenary meetings of the Global Initiative often take place at the level known as Undersecretaries in the United States, roughly equivalent to deputy ministers in other countries—high enough to bring some political clout, but low enough to focus on specific action.

A higher-profile role for the Global Partnership. Already, the participants in the Global Partnership Against the Spread of Weapons and Materials of Mass Destruction have agreed to extend the initiative through 2022. Every G8 summit typically features reports on the projects countries are supporting. It may be possible to convince countries to see the annual G8 summits as an occasion for announcing new nuclear security initiatives, as the nuclear security summits have been—and to create a similar environment in which states do not want to come to the summit “empty handed.” Conceivably states which were not G8 participants but which made substantial nuclear security commitments could be invited to take part in an event with the summit leaders on the margins of the main summit.

A new forum. Finally, interested states could create a new forum, below the summit level but at a high enough level to maintain a high-level impetus for nuclear security. This could take a wide variety of forms, from a continued focus only on nuclear security to various possibilities for a broader focus—for example, a focus on all forms of high-consequence terrorism. One possibility would be biannual ministerial-level meetings, rather than summit meetings.

Nuclear Security for the Long Haul

It is time for the nuclear security effort to shift toward a continuing effort to achieve high standards of nuclear security performance around the world. Nuclear weapons, the materials to make them, major nuclear facilities, and dangerous radiological sources all need effective protection—though the specific security measures needed will vary depending on what is being protected and what adversary capabilities security systems must be able to defeat.

The steps suggested here will not be easy. Complacency, secrecy, sovereignty, politics, cost concerns, and bureaucracy will all pose formidable obstacles that must be overcome. But the very real successes already achieved, detailed in this report, make clear that officials with vision and determination can overcome these obstacles to the benefit of all. Despite this progress, vulnerabilities remain, as do terrorists groups looking for weak points to exploit. After a nuclear or radiological attack, it will be very difficult to explain why practical steps to prevent it, such as those proposed in this report, had not been taken. States around the world need to take action to build a global system that will provide effective nuclear security for as long as nuclear weapons and the materials needed to make them continue to exist.

List of Acronyms

GUMO	12th Main Directorate of the Ministry of Defence (Russian acronym)
AERB	Atomic Energy Regulatory Board
AMIPA	American Medical Isotope Production Act
CPPNM	Convention on the Physical Protection of Nuclear Materials
CISF	Central Industrial Security Force
DAF	Device Assembly Facility
DBT	Design Basis Threat
DOE	Department of Energy
EU	European Union
GICNT	Global Initiative to Combat Nuclear Terrorism
GTRI	Global Threat Reduction Initiative
HEU	Highly Enriched Uranium
ICSANT	International Convention on the Suppression of Acts of Nuclear Terrorism
INPO	Institute of Nuclear Power Operations
INSEN	International Nuclear Security Education Network
IPPAS	International Physical Protection Advisory Service
LEU	Low Enriched Uranium
MCC	Material Consolidation and Conversion
MWe	megawatt-electric
MNEPR	Multilateral Nuclear Environmental Program in the Russian Federation
MPC&A	Materials Protection Control and Accounting
NNSA	National Nuclear Security Administration
NRC	Nuclear Regulatory Commission
OPUK	Basic Rules on Nuclear Material Control and Accounting (Russian acronym)
PFBR	Prototype Fast Breeder Reactor
RTG	Radio-Thermoelectric Generator
SPD	Strategic Plans Division
UNSCR	UN Security Council Resolution
WANO	World Association of Nuclear Operators
WINS	World Institute for Nuclear Security

Note: A glossary of terms associated with nuclear security can be found at <http://nuclearsecurity-matters.belfercenter.org/glossary>.

About the Project on Managing the Atom

The Project on Managing the Atom (MTA) is the Harvard Kennedy School's principal research group on nuclear policy issues. Established in 1996, the purpose of the MTA project is to provide leadership in advancing policy-relevant ideas and analysis for reducing the risks from nuclear and radiological terrorism; stopping nuclear proliferation and reducing nuclear arsenals; lowering the barriers to safe, secure, and peaceful nuclear-energy use; and addressing the connections among these problems. Through its fellows program, the MTA project also helps to prepare the next generation of leaders for work on nuclear policy problems. The MTA project provides its research, analysis, and commentary to policy makers, scholars, journalists, and the public.

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