PROJECT ON MANAGING THE ATOM

Progress on Securing Nuclear Weapons and Materials: The Four-Year Effort and Beyond

BY MATTHEW BUNN,
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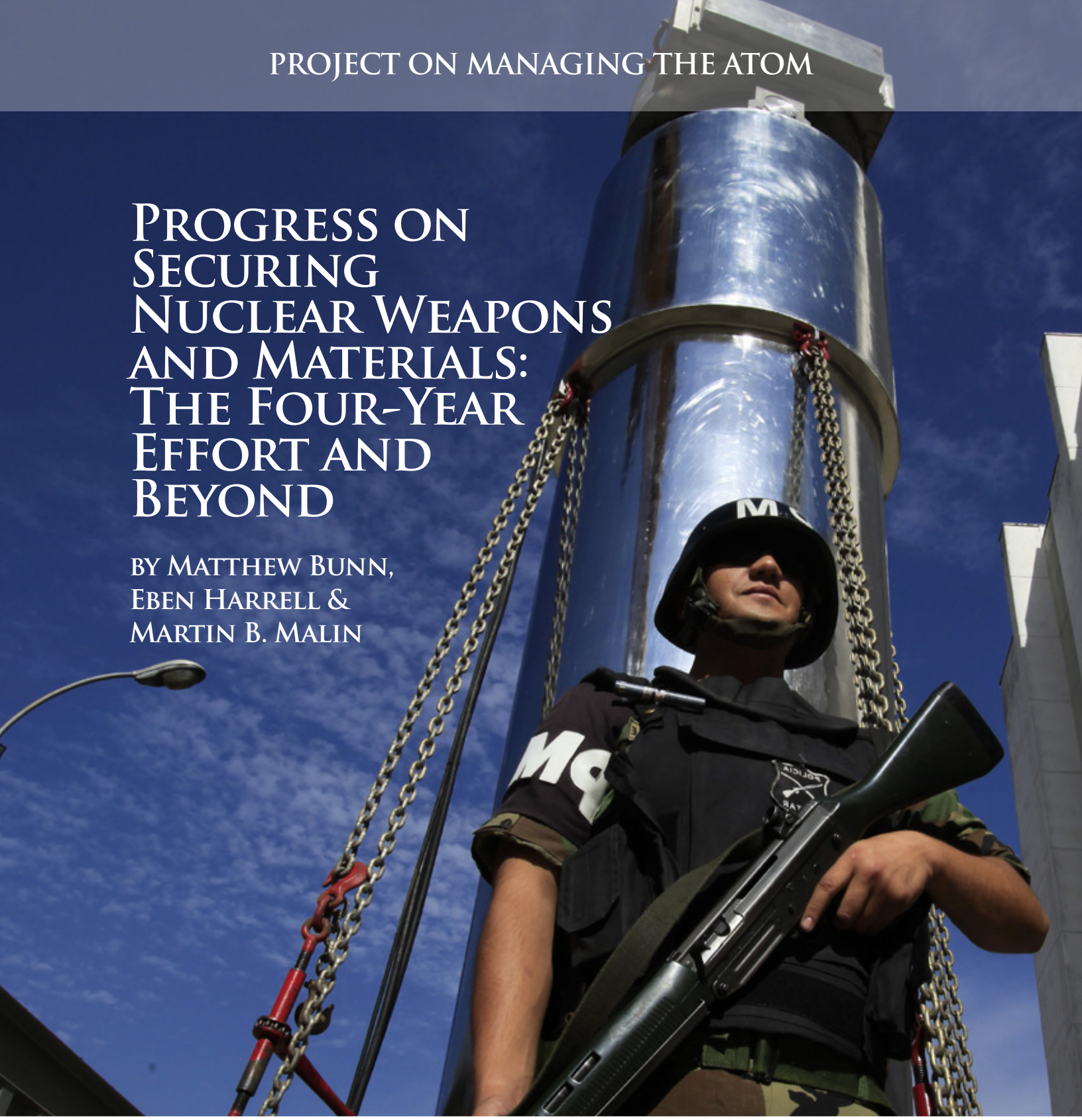

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BELFER CENTER for Science and International Affairs

MARCH 2012

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Acknowledgements

This paper was made possible by generous financial support from the John D. and Catherine T. MacArthur Foundation, with additional funding from the Nuclear Threat Initiative and the Belfer Center for Science and International Affairs. We are grateful to numerous officials of the U.S. government, the International Atomic Energy Agency, and other governments who gave generously of their time, information, and insights; they prefer to remain anonymous. We would like to thank Graham T. Allison, Michelle Cann, Trevor Findlay, Miles Pomper, Simon Saradzhyan, William Tobey, and officials from the U.S. National Nuclear Security Administration and the U.S. National Security Council for comments on an earlier draft. All responsibility for remaining errors of fact and judgment remains with the authors.

Cover Image: A soldier guards a transport cask containing highly enriched uranium being removed from a reactor in Chile. AP Photo/Jorge Saenz

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Introduction

In April 2009, President Obama warned that terrorists were trying to get nuclear weapons or the materials needed to make them, a danger he called "the most immediate and extreme threat to global security." In response, he called for the international community to join in an effort "to secure all vulnerable nuclear material around the world in four years." This four-year effort was endorsed unanimously by the UN Security Council in Resolution 1887 in September 2009 and by the first nuclear security summit in Washington in April 2010. On March 26th and 27th, 2012, leaders and senior officials from more than fifty countries and international organizations will gather in Seoul, South Korea to affirm their commitment to strengthening the security of nuclear and radiological materials worldwide. What should the international community hope to achieve by the end of this four-year effort?[1] What progress has been made to date? What next steps should be taken after Seoul?

In this paper, we offer a definition of appropriate goals of the four-year nuclear security effort and an assessment of how far the international community has come toward fulfilling those goals. Our progress assessment is broken into five categories:

- Improving security for the highest-risk stockpiles;
- Consolidating stockpiles in fewer locations;
- Ensuring that all states with nuclear weapons, separated plutonium, and highly enriched uranium (HEU) have at least a baseline level of security for these stocks in place;
- Strengthening the global nuclear security regime; and
- Improving security practices, training, and culture on the ground.

Having offered a description of the current status of nuclear security efforts, we then recommend next steps—both for the four-year effort and for efforts that will be required for many years to come.

In one sense, the four-year effort to secure nuclear materials can be considered a major success: many of the world's highest-risk nuclear stocks are either receiving significant security improvements or have been eliminated entirely. The risk of nuclear theft and terrorism is lower as a result of these efforts. The nuclear security summit process has elevated nuclear security to the level of presidents and prime ministers, and helped forge a global sense of urgency. By February 2012, roughly 80 percent of the nuclear security commitments made by individual countries at the 2010 nuclear security summit had been fulfilled.[2] Other steps beyond improving nuclear security also reduce the risk of nuclear terrorism. (For a description of other factors that affect this risk, see "Beyond Security for Nuclear Stockpiles," p. 24.)

But major challenges remain. At the current pace it will not be possible to say at the end of four years that all of the world's nuclear stockpiles have effective and lasting security in place. In particular,

[1] Strictly speaking, the four-year effort, which began in April 2009, would culminate in early 2013. The timeline has been somewhat elastic, however, and the Obama administration now counts December 2013 as the end of the four-year effort. See U.S. Department of Energy, *FY 2013 Congressional Budget Request: National Nuclear Security Administration,* DOE/CF-0071, Vol. 1 (Washington D.C.: DOE, February 2012), http://www.cfo.doe.gov/budget/13budget/Content/Volume1.pdf (accessed on 2 February 2012), p. 7. For the purpose of this report, we assume the effort began in April 2009 and will end in December 2013.

[2] See Michelle Cann, Kelsey Davenport, and Margaret Balza, *The Nuclear Security Summit: Assessment of National Commitments* (Washington, D.C.: Arms Control Association and Partnership for Global Security, March 2012), http://www.armscontrol.org/files/ACA_NSS_Report_2012.pdf (accessed 22 March 2012).

nuclear material control and accounting practices—which are particularly important for protecting against insider theft, and for sounding the alarm in a timely way if nuclear material has been stolen—are likely to be slower to improve than physical protection measures such as guards, gates, and intrusion alarms. And even for sites that have received physical protection upgrades, the sustainability of these improvements is in doubt. Hence, it is important both to accomplish as much as possible during the four years and to maintain the momentum of security improvement after the four-year effort is completed. Nuclear security, like nuclear safety, will require constant vigilance and a culture of continual improvement for as long as nuclear weapons and the materials needed to make them continue to exist.[3]

[3] President Obama's four-year nuclear security effort focused specifically on securing "all vulnerable nuclear material around the world," not on securing nuclear facilities against sabotage or improving security for radiological sources, as important as those efforts are. This paper, therefore, also focuses only on securing nuclear weapons and materials.

Approaches to Assessing Nuclear Security Progress

There are several ways to assess progress on nuclear security, each with advantages and disadvantages. One approach is to assess how well countries are doing in meeting a set of standardized benchmarks. Unfortunately, only limited publicly available information is available for such an assessment. This is the approach that the Nuclear Threat Initiative (NTI) has taken with the NTI *Nuclear Materials Security Index*, which offers numerical ratings for nuclear security and a number of related factors for countries all around the world. [1] This index makes an important contribution by offering a consistent and transparent methodology for judging progress in all countries. But because much of the key information about nuclear security is not publicly available, the NTI index relies on a series of indicators (many of them based on whether particular types of rules are or are not in place), not measures of the real effectiveness of nuclear security on the ground. An accompanying interactive website allows readers to see how changes in particular indicators would alter a country's overall ranking.

A second approach is to assess how well countries are doing in fulfilling the commitments they have made to strengthen nuclear security. That approach can also be useful, but does not address the question of how much the completion of the commitments contributes to reducing the overall risk.[2] A third approach would be to assess how much the overall risks of nuclear theft and terrorism have been reduced. Unfortunately, that goal cannot be achieved, as neither classified nor openly available data is sufficient to quantify how much the nuclear security measures taken so far have reduced the risk. Instead, we adopt a fourth approach, which moves as much as is practical toward an assessment of risk reduction. We identify the steps the international community has taken or could take that would have the most impact on the risk of nuclear theft, and assess how much progress has been made toward completing each step, while also assessing how much risk remains and to what extent that risk is declining or increasing.

[1] Nuclear Threat Initiative and Economist Intelligence Unit, *NTI Nuclear Materials Security Index: Building a Framework for Assurance, Accountability, and Action*, (Washington, D.C.: NTI, January 2012); http://www.ntiindex.org/ (accessed 22 March 2012).
[2] See Michelle Cann, Kelsey Davenport, and Margaret Balza, *The Nuclear Security Summit: Assessment of National Commitments* (Washington, D.C.: Arms Control Association and Partnership for Global Security, March 2012).

Nuclear Security Goals

The Obama administration has carefully avoided offering any specific, public definition of what it hopes to accomplish during the four-year effort—a fact that has generated some criticism.[4]

In the absence of an official definition of the specific goals to be accomplished, we offer our own definition here. The officially stated goal is to "secure" all "vulnerable" stocks of nuclear material worldwide. We believe that to accomplish this objective, effective nuclear security measures must be provided for all the stocks that do not currently have them, so that when the goal is fully met, *all* stocks of nuclear weapons, separated plutonium, and highly enriched uranium (HEU) worldwide will be *effectively* and *lastingly* protected against the kinds of threats terrorists have demonstrated they can pose.

All stocks means any nuclear material that could be used to make a nuclear bomb, whether it is in a military or a civilian stockpile. It means the effort must ensure security not just for materials in developing or transitioning countries such as Russia, Pakistan, or South Africa, but also in wealthy countries such as Belgium and Japan—and the United States.

Effectively protecting this material is a matter of reducing risk—another way of stating the goal is that at the end of four years, all nuclear stocks should have a low risk of being stolen. Facilities containing nuclear weapons or weapons-useable materials must be reliably protected against the kinds of adversary capabilities (both outsider and insider) that they are most likely to face. Hence, how much security is enough will vary from country to country (or even between regions within countries), depending on the spectrum of plausible adversary capabilities in each country: a security system that was perfectly adequate in Canada might still be considered "vulnerable" or "high risk" in Pakistan.

But in a world with terrorists with global reach, even in the safest countries, nuclear weapons, HEU, or plutonium must *at least* be protected against one well-placed insider, a modest group of well-armed and well-trained outsiders (capable of operating as more than one team), and both outsiders and an insider working together. In countries facing severe terrorist threats, such as Pakistan, such stocks must be protected against more capable adversaries.[5] Any nuclear weapons or weapons-usable

[4] See, for example, Government Accountability Office, *Nuclear Nonproliferation: Comprehensive U.S. Planning and Better Foreign Cooperation Needed to Secure Vulnerable Nuclear Materials Worldwide*, GAO-11-227 (Washington, D.C.: GAO, 2010), http://www.gao.gov/assets/320/313961.pdf (accessed 14 February 2012). Anne Harrington, the Deputy Administrator for Defense Nuclear Nonproliferation at the National Nuclear Security Administration (NNSA), recently offered the first specific public statement of what the administration hopes that her part of the government will accomplish during the four-year effort, indicating that by December 2013, NNSA would "(1) remove an additional 1,228 kilograms of HEU and Pu (for a total of 4,353 kilograms); (2) clean out all HEU from an additional 8 countries for a total of 27 (14 of which will have taken place during the four-year effort); and (3) convert or shutdown an additional 11 HEU-fueled reactors (for a cumulative total of 88). These are specific goals, which will take considerable effort to achieve, but achieving them would not mean that Obama's originally stated goal of securing all the world's vulnerable nuclear material had been completed. See Anne Harrington, "Statement on Managing Interagency Nuclear Nonproliferation Efforts," (Washington, D.C.: U.S. Senate Homeland Security and Government Affairs Committee, March 14, 2012), http://www.hsgac.senate.gov/download/?id=4d6b4b4a-7e32-44b8-8674-b94e48b7487f (accessed 20 March, 2012).

[5] For a more detailed discussion of such a baseline level of nuclear security, see 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). For a description of the essential elements of effective nuclear security and accounting systems, see Matthew Bunn, "'Appropriate Effective' Nuclear Security and Acounting—What is it?" (paper presented at Global Initiative/UNSCR 1540 Workshop on 'Appropriate Effective Material Accounting and Physical Protection', Nashville, Tennessee 18 July 2008). http://www.belfercenter.ksg.harvard.edu/publications/18452/ (accessed 3 March 2012).

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.

nuclear material that are *not* well-protected against such baseline threats should be considered a priority to be addressed.

"Effective" protection or "low" risk could be achieved by improving protection or by a combination of improving protection and reducing the likely adversary capabilities. In some countries, such as Pakistan, no plausible level of security upgrades will be sufficient to achieve a low level of risk unless measures are also taken to reduce the chance that thieves would be able to mount large outsider attacks or insider conspiracies without detection.

Of course, "low risk" of being stolen is an elastic concept. What seems sufficiently low to one observer may still seem worrisomely high to another. *Assessing the theft risks posed by different stocks around the world will have to be a continuous and ever-evolving part of the effort.* If, at the end of four years, the world has reached a state where the highest-risk remaining stockpiles pose much lower risks than do today's highest-risk stockpiles, the four-year effort will have "succeeded" in the sense of having substantially reduced the overall risk of nuclear theft.

Lastingly means that the international community has reason to believe that stocks of nuclear weapons and weapons-usable nuclear material are likely to continue to be effectively protected for years to come, long after the four-year objective has passed. For example, if a country has put in place regulations requiring its nuclear materials to be protected against a robust spectrum of insider and outsider threats, is effectively enforcing those regulations, and has arranged for appropriate resources to be available to meet those regulations, it would be reasonable to conclude that nuclear security in that country will likely endure. Of course, there are inevitably conflicts between doing things quickly and doing them in a way that will last, and difficult judgments will have to be made as the effort proceeds. If, at the end of four years, all or nearly all of the world's stocks are reliably protected against the main plausible threats in the countries where those stocks exist, and the opera-

tors managing these stocks have the resources and incentives to ensure sustainability—or are at least have made substantial steps on a path toward achieving sustainability—the effort will have made enormous progress.

Addressing the Highest-Risk Nuclear Stocks

The most urgent tasks, of course, are to reduce the risks of nuclear theft where those risks are highest. But how can the world identify those highest-risk stockpiles? The risk of nuclear theft is determined by the quantity and quality of nuclear material available to be stolen (and in particular how hard it would be to make a bomb from it, or to get a detonation from a weapon that might be stolen), the effectiveness of the security measures in place, and the plausible adversary capabilities those security measures must protect against.[6] Based on the limited unclassified information available about these factors, it appears that the highest-risk nuclear stocks are in Pakistan, Russia and at HEU-fueled research reactors with large quantities of HEU. For all three categories, significant progress has been made in increasing nuclear security. But is it not yet possible to say that the risk of theft of nuclear material in Pakistan, Russia or HEU research reactors has been reduced to a low level. In all three cases, challenges remain.

Pakistan

Progress: Unknown

Remaining risk: High

Risk trend: Worsening

Pakistan maintains a small (though growing) nuclear stockpile, in a small number of locations, with extensive security measures. But with al Qaeda's core leadership located there, a dangerous Taliban insurgency, and a range of highly capable terrorist groups with links to the Pakistani state, Pakistan's nuclear assets face a greater threat from extremists seeking nuclear weapons than any other stockpile on earth.

In the last decade, Pakistan has taken major steps to improve security and command and control for its nuclear weapons.[7] While Islamabad maintains a veil of secrecy over the specifics of its nuclear security arrangements, its stockpiles are thought to be under heavy guard, protected by a 1,000-man armed security force overseen by a two-star general, which is part of the larger 8-10,000-person Strategic Plans Division that manages Pakistan's nuclear weapons.[8] Personnel participating in the nuclear program are subject to extensive screening, in a program reported to be comparable to the U.S. Personnel Reliability Program.[9] Pakistani nuclear weapons are believed to be stored in disassembled

[6] For a related discussion of prioritization, see Bunn and Harrell, *Consolidation: Thwarting Nuclear Theft,* (Cambridge, MA: Project on Managing the Atom, Harvard University, 2012), http://belfercenter.ksg.harvard.edu/publication/21818/consolidation.html (accessed 22 March 2012), pp. 4-9.

[7] For an unclassified overview of Pakistan's nuclear security arrangements, see International Institute for Strategic Studies, *Nuclear Black Markets: Pakistan, A.Q. Khan and the Rise of Proliferation Networks: A Net Assessment* (London: IISS, 2007), pp. 112-118.

[8] IISS, *Nuclear Black Markets*, p. 112.

[9] See Feroz Khan, "Nuclear Security in Pakistan: Separating Myths and Reality," *Arms Control Today* (July 8, 2009), http://www.armscontrol.org/act/2009_07-08/khan#41 (accessed 28 January 2010).

form, with the components stored in separate buildings, so that thefts from more than one building would be required to get the complete set of components for a nuclear weapon.[10] U.S. President Barack Obama has stated that he has confidence in Pakistan's nuclear security arrangements,[11] though repeated leaks to the press indicate that many U.S. government officials still have grave concerns.[12]

There is a very real possibility that sympathetic insiders might carry out or assist in a nuclear theft, or that a sophisticated outsider attack (possibly with inside help) could overwhelm even the most stringent defenses. Over the longer term, there is at least a possibility of violent extremists seizing power, or of a collapse of the Pakistani state, making nuclear weapons vulnerable. Although present evidence suggests both of these scenarios remain unlikely, there are worrying trend lines, including the increasing capability of insurgents, governmental dysfunction, tension between civilian and military leaders, worsening economic performance, and ongoing corruption.

Major upgrades of Pakistan's nuclear security apparatus began even before the four-year effort commenced; the United States, however, has reportedly broadened its cooperation with Pakistan since 2009.[13] The specifics of this cooperation are classified, however, and what has been accomplished during the four-year nuclear security effort is not known.

While Pakistani generals share the U.S. concern over extremist threats to their nuclear stockpiles, their first priority is to protect these stocks from Indian strikes—or American seizure. As a result, physical protection measures that make sites with nuclear weapons or materials highly visible—such as large clear zones or boulder fields to prevent adversaries from approaching in vehicles—are not generally used, and Pakistan may disperse its nuclear assets in times of crisis, raising additional vulnerabilities. For the same reasons, Pakistan has not allowed U.S. experts to visit its nuclear sites to help assess what additional security measures might be needed.

Pakistan's fear of a U.S. raid on its nuclear assets is stoked by repeated U.S. press speculation about planning for such possibilities, and was dramatically heightened by the U.S. raid that killed Osama bin Laden in May 2011, in which U.S. special forces were able to enter Pakistan in stealth helicopters, carry out the 40-minute raid, and leave without ever encountering Pakistani forces.[14]

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[10] See, for example, David Albright, "Securing Pakistan's Nuclear Infrastructure," in Lee Feinstein et al., *A New Equation: U.S. Policy toward India and Pakistan after September 11* (Washington, D.C.: Carnegie Endowment for International Peace, 2002), http://www.carnegieendowment.org/files/wp27.pdf (accessed 22 March 2012).

[11] See Ravi Khanna, "President Obama Calls Nuclear Security Summit Day of Great Progress," *Voice of America News* April 14, 2010, http://www.voanews.com/english/news/usa/President-Obama-Calls-Nuclear-Security-Summit-Day-of-Great-Progress--90868504.html (accessed on 17 February 2012).

[12] See Jeffrey Goldberg and Marc Ambinder, "Nuclear Negligence," *The National Journal,* November 4, 2011, http://www.nationaljournal.com/magazine/the-pentagon-s-secret-plans-to-secure-pakistan-s-nuclear-arsenal-20111104 (accessed 7 March 2012).

[13] For early accounts of this cooperation, see, for example, David Sanger and William Broad, "U.S. Secretly Aids Pakistan in Guarding Nuclear Arms," *New York Times*, November 17, 2007 and Joby Warrick, "U.S. Has Concerns Over Security of Pakistan's Nuclear Weapons," *The Washington Post*, November 11, 2007. For a report that President Obama increased the priority the U.S. government placed on improving security for Pakistan's nuclear stockpiles in 2009, see Jane Perlez, David E. Sanger, and Eric Schmitt, "Nuclear Fuel Memos Expose Wary Dance With Pakistan," *New York Times,* November 30, 2010.

[14] See, for example, Seymour Hersh, "Watching the Warheads," *The New Yorker,* 5 November 2001, http://www.newyorker.com/archive/2001/11/05/011105fa_FACT (accessed 22 March 2012), or Christina Lamb, "Elite U.S. Ready to Combat Pakistani Nuclear Hijacks," *The Times* (London)*,* 17 January 2010.Note that while the latter article also provoked Pakistani concern, the specific scenario described was U.S. special forces responding to extremist theft of a nuclear weapon, presumably with the knowledge and cooperation of the Pakistani military, rather than U.S. seizure of

Although the extent of nuclear security improvements in Pakistan is unknown, the following factors make the overall trend toward increasing risk:

- **Growing extremist threats**. Pakistan has seen a sharp rise in terrorist activity in the past few years. Some of these attacks have shown worrisome levels of sophistication. In October 2009, militants wearing Army uniforms attacked Pakistani Army headquarters in Rawalpindi using automatic weapons, rocket-propelled grenades, and explosives (apparently with insider knowledge of the layout of the base); they succeeded in penetrating the base and seizing hostages, and were not defeated by Pakistani forces until many hours later—despite explicit warnings ahead of time that such an attack was being planned.[15] 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 and 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, and appeared to be well trained.[16] Attacks of this kind could pose a significant threat to nuclear weapon and nuclear material sites.
- **The insider threat**. The threat of insiders within Pakistan's military, security, and nuclear establishments is very real—and may be growing. In at least two cases, serving Pakistani military officers working with al Qaeda came within a hair's breadth of assassinating Pakistan's then head-of-state Pervez Musharraf; if the military officers guarding the President cannot be trusted, how much confidence can we have in the military officers guarding the nuclear weapons? Although Admiral Mike Mullen spent much of his tenure as Chairman of the Joint Chiefs of Staff seeking to improve relations with the Pakistani military, he publicly charged that the terrorist Haqqani network, which had just carried out a deadly attack on the U.S. embassy in Kabul, operated "as a virtual arm" of Pakistani Inter-Services Intelligence (ISI)[17]—and a former ISI commander was among the leaders of the Ummah Tameer-e-Nau (UTN) network, which sought to help al Qaeda with nuclear and biological weapons.[18] Will Pakistan's Strategic Plans Division, which controls nuclear weapons, always be able to exclude all personnel with extremist sympathies? The deep and far-reaching corruption in Pakistan also increases the insider threat.
- **The world's fastest-growing nuclear arsenal**. Unclassified estimates suggest that Pakistan's stockpile has grown by an estimated 25% since 2009 and is currently thought to contain around 100 warheads.[19] The country has two plutonium production reactors now operating and two

Pakistan's nuclear weapons against Pakistan's will.

[15] Jane Perlez, "Pakistani Police Had Warned Army About a Raid," *New York Times,* 11 October 2009, http://www.nytimes.com/2009/10/12/world/asia/12pstan.html (accessed 22 March 2012). See also Hassan Abbas, "Deciphering the attack on Pakistan's Army headquarters," *Afpak Channel*, *Foreign Policy*, 11 October, 2009, http://afpak.foreignpolicy.com/posts/2009/10/11/deciphering_the_attack_on_pakistan_s_army_headquarters (accessed 14 March 2012).

[16] Syed Shoaib Hasan, "'New Kind of Militant' Behind Pakistan Karachi Attack," *BBC News,* 23 May 2011 http://www.bbc.co.uk/news/world-south-asia-13508864 (accessed 14 May 2012).

[17] See, for example, Elisabeth Bumiller and Jane Perlez, "Pakistan's Spy Agency Is Tied to Attack on U.S. Embassy., *New York Times*, September 22, 2011, http://www.nytimes.com/2011/09/23/world/asia/mullen-asserts-pakistani-role-in-attack-on-us-embassy.html?pagewanted=all (accessed 17 February 2012)

[18] David Albright and Holly Higgins, "A Bomb for the Ummah?," *Bulletin of the Atomic Scientists* Vol. 59, No. 2 (March/April, 2003), pp. 49-55.

[19] See Hans M. Kristensen and Robert S. Norris, "Nuclear Notebook: Pakistan's Nuclear Forces, 2011," *Bulletin of the Atomic Scientists,* Vol. 67, No. 4 (July/August 2011), pp. 91-99, http://bos.sagepub.com/content/67/4/91.full.pdf (accessed 14 March 2012), and David Sanger and Eric Schmitt, "Pakistani Nuclear Arms Pose Challenge to U.S. Policy,"

more under construction, which will increase bulk processing of fissile material—the stage in the life cycle of nuclear material that historically has proven the most vulnerable to insider theft.[20] Reports suggest the country has developed short-range tactical weapons, which may be more greatly dispersed than Pakistan's strategic arsenal, and may be transferred to the control of field officers during times of crisis.[21]

- **Growing U.S.-Pakistani tensions.** Events such as the U.S. raid that killed bin Laden, the controversy over the alleged effort by the Pakistani ambassador to the United States to get help for Pakistan's civilian government in its struggle with the Pakistani military, and simmering unease over the U.S. drone strikes in Pakistan have led to a sharp downturn in U.S.-Pakistani relations. These tensions are likely to make nuclear security cooperation more difficult, and could imperil funding for the effort.
- **A struggling government.** The Pakistani government remains weak, and faces a daunting array of economic, political, and security challenges. With armed terrorist groups operating throughout the country, the country's leadership has struggled to establish stable governance over its territory. Tensions between the judiciary and executive branches of the government, and between the government and the military, have resulted in an increasingly unstable environment, making decisive action more difficult. While it remains highly unlikely that the Pakistani state will collapse, this scenario cannot be entirely ruled out.

Russia

Progress: Significant

Remaining risk: Medium

Risk trend: Stable or slowly declining

Russia has the world's largest stockpiles of nuclear weapons, plutonium, and HEU, located in the world's largest number of buildings and bunkers. Having recovered from the chaos following the collapse of the Soviet Union, Russia put in place dramatically improved security and accounting measures for its nuclear weapons and materials during the past two decades, with billions of dollars of U.S. help. But significant weaknesses remain in some areas, and its security measures face substantial threats from both corrupted insiders and hostile outsiders. As just one indicator of the problem of corruption in Russia, in 2010 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 of state funds; press reports suggest that Gaidukov's activities included stealing funds from U.S. efforts to beef up nuclear safety and security.[22]

New York Times, January 31, 2011, http://www.nytimes.com/2011/02/01/world/asia/01policy.html?pagewanted=all (accessed 1 March 2012).

[20] Almost all of the known thefts of HEU and plutonium have been of bulk material, such as powders, and were committed without anyone knowing the material was missing until it was seized.

[21] See, for example, Sanjeev Miglani, "Pakistan Builds Low Yield Nuclear Capability, Concern Grows," *Reuters,* May 15, 2012.

[22] "Russian General Dips Into U.S. Taxpayers' Pockets," *Nezavisimaya Gazeta,* 27 December 2010. Gaidukov will soon stand trial for bribery. Russian Legal Information Agency, "General Discharged for False Income Disclosure Took $333K in Bribes," release, 20 February 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,

Terrorists in Russia have also shown the ability to organize and execute large scale overt attacks such as the Moscow theater siege in 2002 and the Beslan school massacre of 2004. After those attacks, the Russian government largely defeated Chechen separatist groups, and killed Shamil Basayev, who had claimed credit for both the Moscow theater and Beslan attacks; Chechen terrorists' ability to organize large-scale attacks in Russia was substantially reduced. During the period of the four-year nuclear security effort, however, the terrorist threat in Russia has been rising again—the movement has regrouped and spread, carrying out dozens of deadly attacks a year, with a new goal of establishing an Islamic caliphate throughout the North Caucasus.[23]

Many nuclear security and accounting improvements in Russia were completed before the four-year nuclear security effort began, through Russia's own efforts and through U.S.-Russian cooperation. That cooperation accelerated as a result of the nuclear security initiative launched by Presidents George W. Bush and Vladimir Putin at a U.S.-Russian summit in Bratislava in 2005, which set a deadline of December 2008 for completing the nuclear weapon and weapons-usable nuclear material upgrades covered by the initiative. Ongoing work includes upgrades at additional buildings housing weapons-usable nuclear material; further upgrades at some locations previously considered completed with a particular emphasis on protecting against insider thefts; issuance of strengthened nuclear security and accounting regulations; efforts to consolidate HEU and convert it to LEU; programs to strengthen security culture; cooperation targeted on laying the groundwork for sites to sustain effective security after U.S. assistance phases out; exchanges of best practices; and continued cooperation to provide adequate capabilities for personnel training and equipment maintenance. In FY 2011, for example, the United States helped fund insider-related upgrades at two of Russia's largest bulk processing facilities, new perimeter fences at two military areas that together contained 24 buildings with weapons-usable material, and material control and accounting improvements at 18 civilian sites with weapons-usable material.[24] The U.S. cooperative program hopes to complete upgrades at 229 buildings by the end of fiscal year (FY) 2013, but some cooperative nuclear security work in Russia is planned to continue for several years thereafter—if the United States and Russia can reach agreement on extending the legal basis for this cooperation, which expires in June 2013.[25]

Nuclear security and accounting improvements in Russia have greatly reduced the risk of nuclear theft; it would now require a sophisticated conspiracy to steal HEU or separated plutonium. Indeed, Russia's official view is that all of its nuclear stockpiles are secure and accounted for, and no further improvements are needed. [26]

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of his duties, though Verkhovstev asserted publicly that the cases were unrelated. Similarly, in 2006, then-President Putin fired Major General Sergey Shlyapuzhnikov, deputy chairman of the section of the Ministry of Internal Affairs responsible for guarding the closed nuclear cities and other close territories, because (according to the Russian state newspaper), he was helping to organize smuggling in and out of these closed territories—in particular, giving out passes that allowed people to go in and out without being checked. "The President Issued a Decree To Dismiss Deputy Chairman of the MVD Department in Charge of Law and Order in Closed Territories and Sensitive Sites, Major General Sergey Shlyapuzhnikov," *Rossiyskaya Gazeta*, 2 June 2006 [translated by Anatoly Dianov].

[23] Simon Saradzhyan, "Russia's North Caucasus: The Terrorism Revival," *International Relations and Security Network* (online), 23 December 2010.

[24] U.S. Department of Energy, *FY 2013 Congressional Budget Request: National Nuclear Security Administration,* p. 416 and 418.

[25] U.S. Department of Energy, *FY 2013 Congressional Budget Request: National Nuclear Security Administration,* p. 407.

[26] Russia's statement for the 2010 nuclear security summit provides a remarkable summary of this view. See Office of the Russian President, "Statement of the Russian Federation on Nuclear Security," 13 April 2010, http://news.kremlin.ru/ref_notes/520 (accessed 24 February 2012). (In Russian.)

Unfortunately, however, some significant nuclear security weaknesses remain in Russia, which might be exploited by sophisticated adversaries—or might already have been exploited in the past. Most facilities, for example, have never measured the contents of the thousands of canisters of nuclear material built up over decades, many of which use easily defeated wax or lead seals. No one knows whether the material in some of those canisters may have been stolen long ago. For today's processing operations, facilities keep accurate nuclear material accounts, but the statistical analyses of the accounting records necessary to detect ongoing thefts of small amounts of material at a time are still not required (and mostly not done) in Russia. Although Russia has a well-trained professional guard force for nuclear weapons, many of the armed guards at Russian weapons-usable nuclear material facilities are poorly paid and poorly trained conscripts, who would be no match for a well-armed, well-trained attack.[27]

At the same time, Russia still has a long way to go to consolidate nuclear weapons and material from the huge number of buildings and bunkers where such stocks are stored and handled. There have been some consolidation efforts, such as at Russia's largest nuclear fuel manufacturer Elektrostal, which last year announced a plan to consolidate all HEU operations into one or two buildings equipped with advanced real-time computerized accounting and control systems.[28] Russia has closed two of its four nuclear weapons assembly and disassembly plants, one of its two nuclear weapons component manufacturing facilities, and all three of its plutonium production reactors—which continued to operate because they provided heat and power to tens of thousands of people in Siberia. But there are still stocks of weapons-usable nuclear material in more than 200 buildings—and Russia has made no overall plan to consolidate these stocks.

What is more, it remains uncertain how well Russia will sustain and upgrade over time the improved nuclear security and accounting measures that have been put in place. Many Russian sites have limited resources to pay for nuclear security, and the Russian government does not appear to be providing additional funds as U.S. nuclear security assistance phases down. Moreover, some important security and accounting measures are not yet required by Russian regulations, and it seems likely that sites will invest only in measures they are required to have in place. In contrast to the 1990s, the Russian government now has the resources to pay for effective nuclear security itself, but Russia has not made nuclear security spending a priority. The legal basis for U.S.-Russian cooperation on nuclear security expires in 2013, and renewal is uncertain.[29]

Research reactors with enough HEU for a gun-type bomb

Progress: Significant

Remaining risk: Medium

Risk trend: Declining

Over 120 research and training reactors around the world still use HEU either as fuel or as targets for producing medical isotopes. Many of these facilities—some on university campuses—have only

[27] Interviews with U.S. and Russian participants in nuclear security cooperation, 2010-2012.

[28] See Viktor G. Bozin and Vladimir A. Mosolov, "Materials Controls and Physical Protection Systems for the Consolidated Production Building at the OAO 'MSZ' Site in Elektrostal, Russia," in *Proceedings of the 52nd Annual Meeting of the Institute for Nuclear Materials Management*, Desert Springs, Calif., 17-21 July 2011 (Northbrook, Ill.: INMM, 2011).

[29] Congress, however, has extended the legal authority for U.S. programs to cooperate on nuclear security in Russia through 2017. See *National Defense Authorization Act for Fiscal Year 2011*, Public Law 111-383, Section 3119.

minimal security measures in place, in some cases little more than a night watchman and a chain-link fence. Many, however, have only modest amounts of HEU on-site. The research reactors that pose the highest risks of nuclear theft are those that have substantial quantities of high-quality HEU—in particular, enough HEU for the simplest "gun-type" nuclear bomb, which would be easiest for terrorists to build. Such a bomb requires 50-60 kilograms of 90% enriched HEU, and more if the enrichment level is lower.[30]

The reactor types of most concern are critical assemblies and pulsed reactors, which often have hundreds of kilograms or even tons of high-grade HEU on-site. In the United States, after years of failed security tests for critical assemblies at a site known as Technical Area 18 (TA-18) at Los Alamos, hundreds of kilograms of HEU in four critical assemblies were shipped to the highly secure Device Assembly Facility at the Nevada National Security Site (formerly the Nevada Test Site). A critical assembly from Livermore was moved to the DAF as well.

Today, two-thirds of the critical assemblies and pulse reactors in the world are in Russia. Russia has far more of each of these types of reactors than it could possibly need, and could save money and improve security by shutting many of them down or converting them to LEU fuel. To date, however, Russia has not committed to take any of these steps.

Outside Russia, the four-year effort is making substantial progress in addressing the security risks at the small number of research reactors and related institutes that have large quantities of HEU on-site:

- **Ukraine**. At the 2010 Nuclear Security Summit, Ukraine announced that it would eliminate all the HEU on its soil, including some 75 kilograms of weapon-grade HEU powder at a research center in Kharkiv. A substantial fraction of Ukraine's HEU has already been shipped to Russia for blending to LEU, and the last is expected to be shipped in the first half of 2012. Ukraine would then become the first country with a site with enough HEU for a gun-type bomb to eliminate all its weapons-usable nuclear material.
- **Belarus**. In December 2010, Belarus agreed to eliminate all the HEU on its soil. But after the United States imposed sanctions over election irregularities, Belarus "froze" its cooperation on HEU removals (although a portion of the HEU had already been shipped). Talks focused on renewing this arrangement are continuing, as are security upgrades for the site where the HEU is located.
- **South Africa**. Since the four-year effort began, South Africa has completed substantial security upgrades at Pelindaba, where its HEU is located (and where there was an unsolved attack by two armed teams in November 2007).[31] South Africa has converted its research reactor at Pelindaba to use LEU fuel, and is in the process of converting the targets it uses for medical isotope production from HEU to LEU. South Africa has shipped some irradiated U.S.-origin HEU fuel back to the United States. South Africa has not committed to eliminating the hundreds of kilograms of weapon-grade HEU left over from its weapon program, but talks on that subject are ongoing.

[30] 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).

[31] One of the teams penetrated a 10,000-volt security fence and turned off the intrusion detectors before proceeding to the emergency control center, where they shot a site employee in the chest after a brief struggle. They spent some 45 minutes inside the guarded perimeter without ever being engaged by site security forces. See Matthew Bunn, *Securing the Bomb 2008* (Cambridge, MA: Project on Managing the Atom, Harvard University, and Nuclear Threat Initiative 2008); http://www.nti.org/securingthebomb, pp. 3-4.

- **Japan**. Japan's Fast Critical Assembly has hundreds of kilograms of weapon-grade HEU metal. There is little continued need for this facility. Japan has not committed to close this facility or convert it to use less-enriched material, and there is no public indication that Japan has upgraded security for the facility since the four-year effort began.

Most other research reactor facilities outside of Russia with enough HEU for a nuclear weapon are at military sites, and are believed to have effective security measures in place. Nevertheless, since no security system is perfect, states where these facilities exist should consider shutting them down and eliminating their HEU.

While few HEU research reactors with large stocks of HEU in Russia have converted or shut down, U.S.-funded programs such as the Global Threat Reduction Initiative (GTRI) are making substantial progress in addressing the research reactors and related facilities with the largest stocks of HEU elsewhere, so the trend in this category is one of declining risk. By the end of the four-year effort, it seems likely that it will be possible to say that the risk of nuclear theft for all but one or two of the HEU-fueled research reactors outside of Russia that have enough HEU for a gun-type bomb will have been reduced to a low level.

Consolidating Nuclear Stockpiles

Progress: Significant, but many categories not addressed

Remaining risk: Medium

Risk trend: Declining

The only way to completely eliminate the risk that nuclear weapons or weapons-usable material will be stolen from a particular site is to eliminate the weapons or material, so that there is nothing left there to steal. Countries can achieve higher security at lower cost by protecting fewer places. Hence, consolidating nuclear weapons and materials to fewer locations is a key part of the nuclear security agenda.[32] In this section, we discuss consolidation efforts going beyond the few research reactor sites with large quantities of HEU discussed above.

While both nuclear weapons and weapons-usable nuclear material now exist in dramatically fewer locations than they did in the 1970s and 1980s, 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 U.S. nuclear weapons are stored).[33] Weapons-usable nuclear material exists in hundreds of buildings in some 32 countries around the world.[34]

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[32] For a more detailed account of priorities and next steps for consolidation, see Bunn and Harrell,*Consolidation: Thwarting Nuclear Theft.*

[33] See Robert S. Norris and Hans M. Kristensen, "Nuclear Notebook: Worldwide Deployments of Nuclear Weapons, 2009," *Bulletin of the Atomic Scientists*, November/December 2009, http://bos.sagepub.com/content/65/6/86.full (accessed 27 February 2012).

[34] See Nuclear Threat Initiative, *NTI Nuclear Materials Security Index, Building a Framework for Assurance, Accountability, and Action (*Washington D.C.: Nuclear Threat Initiative, January 2012), http://www.ntiindex.org/ (accessed 20 February 2012), and International Panel on Fissile Materials, *Global Fissile Material Report 2011: Nuclear Weapons and Fissile Material Stockpiles and Production* (Princeton, N.J.: Program on Science and Global Security, Princeton University, 2011); http://www.ipfmlibrary.org/gfmr11.pdf.

Existing consolidation programs are making significant progress in reducing the number of civilian sites using HEU. Since 1978, when that effort began, some 62 HEU-fueled reactors have converted to LEU fuel and over 120 have shut down without converting.[35] Some 20 countries have eliminated all the weapons-usable nuclear material on their soil. Since 1996, U.S. programs have contributed to removing all the weapons-usable material from over 50 total sites outside the United States and Russia.[36] There has also been substantial progress in consolidating both military and civilian HEU and plutonium within the U.S. nuclear complex (and some modest progress in reducing the number of buildings where plutonium and HEU exist in Russia's nuclear complex). In a very real sense, the removed material represents bombs that will never go off.[37]

Overall, since President Barack Obama launched the four-year effort in April 2009, GTRI has helped to eliminate all HEU from six countries: Chile, Libya, Romania, Serbia, Taiwan, and Turkey.[38] That compares with four countries cleaned out in the three years before President Obama's Prague speech.[39] Since April 2009, GTRI has helped remove almost 1,000 kilograms of HEU from more than 10 countries, maintaining roughly the same pace as in the three years before the four-year effort began.[40] GTRI has helped with conversion or confirmed the shutdown of 14 HEU-fueled reactors since April 2009, a slight decrease in pace compared to the three years before the four-year effort began.[41]

But there is a great deal yet to be done. Over 120 research or training reactors still use HEU fuel or targets—with Russia having a larger number than any other country. While conversions and shutdowns to date have reduced the annual consumption of HEU by some 400 kilograms since 2000, research reactors still use almost twice that amount of HEU every year.[42] Current plans for converting HEU-fueled research reactors are not slated to be completed until 2025—more than a decade after the four-year effort will be completed.[43] 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.[44]

- There has been only modest consolidation progress in Russia, which has the world's largest number of nuclear weapon storage sites, the world's largest number of buildings with plutonium

[35] Figures updated from Ole Reistad and Styrkaar Hustveit, "Appendix II: Operational, Shut Down, and Converted HEU-Fueled Research Reactors," *Nonproliferation Review*, Vol. 15, No. 2 (July 2008); http://cns.miis.edu/npr/pdfs/152_reistad_appendix2.pdf. We are grateful to Strykaar Hustveit and Frank von Hippel for data on these topics.
[36] Data provided by NNSA, January 2010, updated with removals during 2010-2011, and adding removals outside the United States and Russia that were assisted by U.S. programs but are not included in GTRI's data, such as the removal of HEU from Georgia in 1998.
[37] See Anthony Wier and Matthew Bunn, "Bombs That Won't Go Off," *Washington Post,* November 19, 2006.
[38] Data provided by NNSA, February 2012. See also U.S. Congress, Government Accountability Office, *Nuclear Nonproliferation: Comprehensive U.S. Planning and Better Foreign Cooperation Needed to Secure Vulnerable Nuclear Materials Worldwide*, GAO-11-227, December 2010, http://www.gao.gov/new.items/d11227.pdf (accessed 3 March 2012).
[39] Those countries are Portugal (2008), Bulgaria (2008), Latvia (2008), and South Korea (2007). Data provided by NNSA, January 2010.
[40] Data on shipments through 1 February 2012 provided by NNSA, February 2012. Data on shipments in earlier periods provided by NNSA, January 2010.
[41] Data on conversions through 1 February 2012 provided by NNSA, February 2012. Data on conversions in earlier periods provided by NNSA, January 2010.
[42] Ole Reistad's Untitled Presentation at the 2nd International Symposium on HEU Minimization (Vienna, Austria: January 2012), https://www.nti.org/media/pdfs/Reistad_-_HEU_Symposium__Vienna_23_jan_2012.pdf?_=1328045837 (accessed 23 February 2012).
[43] Data provided by NNSA, March 2012.
[44] For more detail, see Bunn and Harrell, *Consolidation: Thwarting Nuclear Theft*.

or HEU, and the world's largest number of HEU-fueled research reactors (including some two-thirds of the world's HEU-fueled critical assemblies and pulse reactors, which, as noted earlier, often have hundreds of kilograms or tons of high-quality HEU).

- There are no current programs targeted on consolidating nuclear weapons to fewer locations.
- Except for a few small stockpiles (amounting to less than 100 kilograms in total) there are no current programs for consolidating separated plutonium to fewer locations.
- Tons of civilian HEU are not yet targeted for removal or elimination.

In short, while significant consolidation progress is being made during the four-year effort, some needed consolidation efforts are not yet underway; some are planned but are likely to face major challenges; and still others are underway but likely to stretch far beyond the end of the four-year effort.

Achieving a Baseline Level of Nuclear Security

Progress: Modest

Remaining risk: Medium

Risk trend: Slowly declining

A variety of pathways and initiatives help the move toward a world in which all facilities and transports with nuclear weapons, HEU, or separated plutonium have at least a baseline level of nuclear security in place. Gaining international agreement that countries would put an agreed-upon level of security in place would be one approach; strengthening individual countries' national rules and practices is another; removing material entirely from some of the facilities that did not meet such a baseline level of security would be a third; fourth and finally, in some cases individual sites or transporters may upgrade security voluntarily to such a baseline level even if that is beyond what is required.

As laid out below in the discussion of the global regime, there is no binding international agreement that specifies how secure nuclear weapons or weapons-usable nuclear material should be. UN Security Council Resolution 1540 requires every state with nuclear weapons or "related materials" to provide "appropriate effective" security and accounting for them, but there has not yet been any agreement on what essential elements are required for a systems to be considered "appropriate effective."[45] As we explain in greater detail below, a revised edition of the IAEA's physical protection recommendations has been completed, which may over time lead to strengthening of national practices and regulations, but this remains very general and does not indicate what kinds of threats nuclear weapons and weapons-usable nuclear material should be protected against.

So far, however, progress in strengthening national-level nuclear security practices around the world during the four-year effort has been modest. There is no publicly available evidence that most of the countries with weapons-usable nuclear materials have made significant changes in their nuclear security rules or procedures. A small number of countries, however, have announced significant changes to their nuclear security regulations and practices. In South Africa, not only have major security upgrades been implemented at the only site with HEU, but also new regulations requiring such sites to be protected against a specified design basis threat (DBT) have been developed, though it appears that they are not yet formally in force.[46] Belgium has reportedly undertaken significant nuclear secu-

[45] For a first cut at such a definition, see Bunn, "'Appropriate Effective' Nuclear Security and Accounting—What is It?"
[46] Apparently the site already considers the DBT rules to be a requirement. Personal communication with South Afri-

rity improvements since the spring of 2009.[47] Japan and the United States have established a high-level joint working group on nuclear security, Japan has upgraded the protection of its nuclear power plants from attack by the sea, and in the aftermath of the Fukushima disaster, Japan has moved to strengthen the independence and capability of its nuclear regulatory agency, which will presumably improve regulation of nuclear security as well.[48] It appears, however, that Japan's nuclear security requirements are still relatively modest, and some press reports suggest that nuclear security weaknesses were revealed during the Fukushima incident.[49] South Korea, which does not have stocks of HEU or separated plutonium, but has a substantial number of nuclear reactors and spent fuel, implemented new regulations requiring its nuclear facilities to protect against a specified design basis threat.[50]

Some facilities implement upgrades voluntarily, sometimes with help from national governments. In the United States, for example, the four remaining HEU-fueled research reactors regulated by the Nuclear Regulatory Commission (NRC) are exempted from most NRC physical protection requirements, but NNSA has paid for all them to implement substantial security upgrades on a voluntary basis, going well beyond what the NRC requires. None of these facilities would be able to provide the kind of baseline level of protection suggested in this paper. Though their fuel is typically quite radioactive and would not be likely to be at the top of the target list for nuclear thieves, it is nonetheless important for the United States to ensure that these facilities have effective security and ultimately to remove the HEU from them, as it is very difficult to convince other countries to do what the United States is not willing to do itself.

Strengthening the Global Regime

Progress: Significant

Remaining risk: Medium

Risk trend: Slowly declining

The international policy framework for nuclear security includes many different elements, each of which contributes to reducing the risk of nuclear terrorism, or has the potential to do so in the future. Overall, however, the framework remains weak: there are no specific global standards for how secure

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can security manager, March 2011. But as of the spring of 2011, they had not been formally issued. Annual reports of the South African Department of Energy (formerly included in the Department of Minerals and Energy) stretching back to before the 2007 break-in have reported continuing work, but successive delays, in getting DBT regulations issued and into force. The report covering April 2010-March 2011 indicates that they planned to develop "appropriate" physical protection regulations for nuclear facilities by March 2011, but that they failed to complete them because they were told to consult further with the Department of Defense. See South African Department of Energy, *Annual Report 2010/2011* (Pretoria: Department of Energy, 2011), p. 61 and 67.

[47] Discussions with Department of Energy official, December 2011.

[48] Discussions with Department of Energy official, December 2011, and with National Security Council official, March 2012. See also CNN Wire Staff, "Japan Redesigns Nuclear Safety Agency After Fukushima," *CNN Online*, August 15, 2001, (http://www.cnn.com/2011/WORLD/asiapcf/08/15/japan.nuclear/index.html) accessed on 3 March 2012).

[49] See: Yuku Hayashi, "Panel Says Crisis Showed Facilities' Terrorism Risks," *The Wall Street Journal*, February 29, 2012. Japan first implemented requirements that sites have security in place able to protect against a specified DBT in 1995, but the estimated cost to all licensees combined to comply with the new regulations was in the range of $50 million, suggesting that the requirements were not very stringent. Personal communication with Japanese regulator, November 2006.

[50] Briefings by South Korean officials, May 2011.

nuclear weapons or weapons-usable nuclear material should be; there are no inspections or other mechanisms to build confidence that states are fulfilling their nuclear security obligations; and there is no agreed approach to continuing a high-level dialogue on nuclear security after the nuclear security summit process comes to an end, as is likely to occur after the third summit in 2014. The job of filling each of those gaps is likely to extend far beyond the end of the four-year effort. Nevertheless, the international community has taken a number of important steps during the four-year nuclear security effort.

New IAEA recommendations on physical protection

The IAEA's recommendations on physical protection are the closest thing to a global nuclear security standard that exists today. While these are purely advisory, most states follow them, 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 2011—for the first time since the 9/11 attacks—member states completed a revision of these recommendations.[51] The new revision contains more specific recommendations that states should require that all facilities with enough weapons-usable nuclear material to be a significant step toward getting a bomb be protected against a specified DBT (though it did not suggest any baseline level of threat that all states should protect these materials against); it called 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 expanded its coverage of protecting nuclear facilities against sabotage. 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."[52]

Nevertheless, while more detailed than many of the other elements of the nuclear security regime, the revised IAEA recommendations are still quite vague. For example, the recommendations specify that "Category I" nuclear material—the type and quantity requiring the highest levels of nuclear security—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.

The IAEA's new recommendations constitute a genuine, if modest, step forward. Countries are only beginning, however, to change their practices based on these recommendations.

Ratifications of nuclear security-related conventions

There are several legally binding instruments for nuclear security, but they are far less specific than the IAEA recommendations. The Convention on the Physical Protection of Nuclear Materials

[51] 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 3 February 2012).

[52] 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).

(CPPNM) includes a variety of useful provisions on criminalizing nuclear theft and smuggling and giving all parties jurisdiction to prosecute such crimes, but its physical protection provisions apply only to material in international transport. A 2005 amendment to the convention, which has not yet entered into force, extended the convention's terms to cover materials in domestic use, storage, and transport, and to cover sabotage of nuclear facilities as well as nuclear theft. But the amended convention's requirements are very general. It says, for example, that countries should set national rules for nuclear security; it says nothing about what those rules should be.[53] Similarly, the International Convention on the Suppression of Acts of Nuclear Terrorism (ICSANT), which entered into force in 2007, requires parties to "make every effort to adopt appropriate measures to ensure the physical protection of radioactive materials," but says nothing about what measures would be appropriate, beyond mentioning that states should take into account relevant IAEA recommendations.[54]

Progress on getting more states to join these conventions has been slow and is summarized in Table 1 below. The pace of ratification of the 2005 amendment to the Convention on Physical Protection quickened with the beginning of the four-year effort—nearly twice the number of states have ratified since April 2009 as did in the previous three years—bringing the total to 52.[55] Some 45 more states, however, still need to ratify for the amendment's entry into force; at the current, post-April 2009 rate, that would take another two and a half years. After the amendment enters into force, it is likely to take additional time before it is reflected in strengthened nuclear security practices at nuclear sites. The pace at which states are joining the International Convention on the Suppression of Acts of Nuclear Terrorism has actually slowed since beginning of 4-year effort. Only 77 states have joined the treaty since it opened for signature.[56]

Table 1: Expansion of legal commitments before/after start of 4-year effort

	ICSANT		CPPNM		CPPNM Amendment	
	2007-09	2009-11	2007-09	2009-11	2007-09	2009-11
# States joining*	31	25	16	6	14	23

*By joining, we mean acceptance, accession, or ratification, i.e. agreeing to be legally bound by the language of the treaty

[53] 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 3 February 2012).
[54] 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 3 March 2012).
[55] See International Atomic Energy Agency, *Amendment to the Convention on the Physical Protection of Nuclear Material* (Vienna, IAEA, updated 13 December 2011), http://www.iaea.org/Publications/Documents/Conventions/cppnm_amend_status.pdf (accessed 3 February 2012).
[56] United Nations Treaty Collection, Databases, Chapter XVIII, 15, "International Convention on the Suppression of Acts of Nuclear Terrorism," http://treaties.un.org/Pages/ViewDetailsIII.aspx?&src=UNTSONLINE&mtdsg_no=XVIII-15&chapter=18&Temp=mtdsg3&lang=en#Participants (Accessed Feb 2, 2012).

Of course, what matters as a measure of progress is not only how fast states are signing on to new security obligations, but *who* is signing up and who is not. (See Table 2 for a summary). Sixteen states that possess weapons-useable nuclear material have not joined the ICSANT; five states from the same group have never ratified the Convention on Physical Protection; and 15 of these states have not ratified the amendment to the CPPNM. Among those who have not ratified either the ICSANT or CPPNM amendment are the majority of countries that possess nuclear weapons, including France, Israel, North Korea, Pakistan, and the United States. One goal of the upcoming nuclear security summit will certainly be to convince additional countries to ratify the amendment.

Table 2: States with Weapons-Useable Nuclear Material That Have Not Ratified Nuclear Security Treaties

ICSANT	CPPNM	CPPNM Amendment
Argentina	France	Belarus
Australia	Iran*	Belgium
France	North Korea*	Canada
Ghana	Syria*	France
Iran*	Vietnam*	Ghana
Israel		Iran
Italy		Israel
Jamaica		Italy
Nigeria*		Jamaica
North Korea*		Japan
Norway		Mexico
Pakistan*		North Korea
Sweden		Pakistan
Syria		South Africa
United States		Sweden
Vietnam*		Syria
		United States
		Uzbekistan
		Vietnam

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

Renewed and expanded Security Council resolutions

UN Security Council Resolution (UNSCR) 1540, approved unanimously in 2004, requires *all* states to provide "appropriate effective" security and accounting for all nuclear weapons or related materials, along with export and border controls, and more. To date, however, no one has defined what es-

sential elements must be in place to comply with these requirements.[57] In 2011, the Security Council extended for 10 years the life of the committee that oversees the implementation of UNSCR 1540. The committee's new mandate includes identifying "effective practices" and providing states with guidance and templates for implementation. The United States has provided additional funding to the committee to enable it to function more effectively.

UNSCR 1887, approved unanimously in September 2009, endorses the four-year effort to secure vulnerable nuclear material, calls 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 is non-binding, unlike UNSCR 1540.

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 U.S.-funded cooperative threat reduction efforts (originally known as Nunn-Lugar, after the two Senators who sponsored the original legislation). A number of these efforts have been extended and expanded during the four-year effort.

The Global Partnership Against the Spread of Weapons and Materials of Mass Destruction was established at the G8 summit in Kananaskis, Canada, in 2002, with the aim of providing $20 billion over 10 years for a broad range of threat reduction efforts, primarily in Russia and the states of the former Soviet Union. In 2011, the participants agreed to extend the partnership for another 10 years and expand it to help countries around the world strengthen nonproliferation controls, including those mandated by UNSCR1540, with nuclear security a key priority. This could help focus additional resources on nuclear security—but other than the United States (which indicated it planned to spend another $10 billion on threat reduction in the coming decade), the participating countries, now numbering 24, did not pledge any additional funds to implement the expanded agenda.[58]

The Global Initiative to Combat Nuclear Terrorism was launched by the United States and Russia in 2006. 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. Unlike the Global Partnership, it is not a major mechanism for channeling nuclear security funding. The Obama administration has sought to strengthen the initiative, and Obama himself pledged in the Prague speech that launched the 4-year-effort to turn the Global Initiative into a "durable" institution. He has had limited success, however; only seven additional countries have joined the initiative since 2009, bringing the total to 82, and there has been no steps to ensure the initiative remains a permanent international institution.[59]

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[57] 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 27 February 2010).

[58] See "G8 Leaders Agree to Extend Global Partnership Beyond 2012," U.S. Department of State press release (Washington, D.C., 3 June 2011) http://www.uspolicy.be/headline/extension-partnership-against-weapons-mass-destruction (accessed 16 March 2012) and Kenneth Luongo, "Nuclear Security Governance for the 21st Century: Assessment and Action Plan" (Washington, D.C.: U.S.-Korea Institute at the Johns Hopkins School of Advanced International Studies, March 2012), http://www.partnershipforglobalsecurity.org/PDFFrameset.asp?URL=http://uskoreainstitute.org/wp-content/uploads/2012/03/USKI_NSS2012_Luongo.pdf (accessed 16 March 2012), p. 8.

[59] For figures on the number of countries participating, see "The 2009 Plenary Meeting of the Global Initiative to

U.S. bilateral nuclear security cooperation with Russia, described above, was well under way before the four-year effort began, and has not been greatly affected by it. The agreement that provides the legal basis for this cooperation will expire in 2013.

Improving Nuclear Security Practices on the Ground

Progress: Moderate

Remaining risk: Medium

Risk trend: Declining

Ultimately, the goal of most of the measures discussed in this paper is to improve the level of nuclear security as actually practiced at nuclear sites and transport operations around the world. But there are many factors that affect nuclear security effectiveness that do not derive directly from the international nuclear security regime or national rules. Does the senior management of the operator understand the threat, make nuclear security a priority, and provide incentives to encourage staff to continually improve nuclear security?[60] Do these organizations have the resources and commitment to sustain effective security for the long haul? Have these organizations built strong security cultures, so that all relevant staff make security a priority every day? Do these organizations learn from the nuclear security experiences of others and implement best practices? Do security-relevant staff have the training they need to do their jobs effectively? The answers to these questions will play a major role in determining the risk that nuclear weapons or weapons-usable nuclear material might be stolen and fall into terrorist hands.

Management priority

No one has collected systematic data on how the level of attention the senior management of nuclear operators are focusing on nuclear security has changed over time. The nuclear security summit process and the parallel industry summits organized in Seoul and beyond have surely contributed to convincing managers that nuclear security is an issue of concern at the highest levels of government and industry. The focus at the World Institute for Nuclear Security (WINS) has placed on corporate governance of nuclear security is also contributing.[61] In many nuclear organizations, however, it remains the case that managers tend to dismiss security threats as extremely unlikely. For many staff, achieving safety is a topic of daily focus, and security is something one gets a briefing on once a year.

Combat Nuclear Terrorism Nuclear Threat Initiative Media Note," U.S. Department of State press release 15 June 2009, http://www.state.gov/r/pa/prs/ps/2009/06a/124723.htm (accessed 16 March 2012) and Luongo, "Nuclear Security Governance for the 21st Century," p. 8.

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

[61] WINS is a relatively new membership organization, launched in Vienna in 2008, where nuclear operators can exchange ideas and best practices with their peers related to improving nuclear security. Information on WINS is available at its website, http://www.wins.org (accessed 17 February 2010). See also Roger Howsley, "The World Institute for Nuclear Security: Filling a Gap in the Global Nuclear Security Regime," *Innovations: Technology, Governance, Globalization*, Vol. 4, No. 4 (Fall 2009), pp. 203–208.

Sustainability

To sustain effective security for the long haul, operators must have the needed financial and personnel resources, and the commitment to applying those resources to the goal of effective security. As many nuclear security managers will not invest in expensive new security measures unless the government tells them they have to, effective regulation is a critical element of sustainability, reinforcing the need to focus on achieving such effective regulation. Providing sufficient resources is another key issue. Particularly at small nuclear facilities that bring in little revenue—such as research reactors—the cost of effective security can be difficult to bear. Governments around the world—which typically subsidize the operations of such small nuclear facilities in one way or another—need to ensure that funds are allocated to ensure that all facilities or transporters handling nuclear weapons, HEU, or separated plutonium have the resources to provide effective security for them.

Some progress is being made in achieving sustainability. The Russian military has reported that they have asked for and received additional funding from the Russian government to cover the cost of maintaining some of the security measures that have been installed.[62] As U.S. funding for nuclear security in Russia winds down, U.S. programs have helped Russian operators develop plans for financing nuclear security without U.S. funds. But nuclear security remains significantly under-funded in Russia and in some other countries. All countries must commit to providing adequate resources to ensure effective security over the long haul. Convincing them to do so should be a central focus of international nuclear security efforts.

Security culture

The human factor is a critical element in nuclear security. If guards are turning off intrusion detectors because they are annoyed at having to check out the false alarms, or patrolling with no ammunition in their guns, even extensive sets of security equipment may not provide good security. As Gen. Eugene Habiger, former DOE "security czar" and former commander of U.S. strategic forces, put it: "good security is 20 percent equipment and 80 percent culture."[63]

Some progress is being made in strengthening security culture in nuclear organizations around the world. Driven in some cases by a reaction to particular incidents (such as the 9/11 attacks, or the break-in at the Pelindaba nuclear site in South Africa in 2007), some organizations have transformed their cultures and dramatically increased their focus on security. The IAEA and WINS have both published guides on how organizations can improve their security cultures, and many countries have taken advantage of the security culture workshops offered by these organizations and others.[64] The United States and Russia have established a security culture working group that has developed a wide range of materials and approaches, and have established targeted programs to strengthen security culture at several sites. These security culture programs have expanded significantly since the four-year effort began.

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[62] Bunn, *Securing the Bomb 2008*, p. 28.

[63] Interview by author (Bunn), April 2003.

[64] See International Atomic Energy Agency, "Nuclear Security Culture: Implementing Guide," (Vienna: IAEA, 2008), http://www-pub.iaea.org/MTCD/publications/PDF/Pub1347_web.pdf (accessed 12 March 2012); and World Institute for Nuclear Security, "Nuclear Security Culture, Revision 2.0" (Vienna, Austria: World Institute for Nuclear Security, September 2011). Nuclear security culture activities were one of the most common type of national commitment at the 2010 nuclear security summit. See Cann, Davenport, and Balza, *The Nuclear Security Summit: Assessment of National Commitments,* p. 8.

But organizational cultures are very difficult to change. Many professionals in the nuclear industry continue to doubt the credibility of security threats, and put a low priority on security. In many organizations, the reality is that an hour spent complying with security rules or finding ways to strengthen security is less likely to get you a promotion or a salary increase than an hour spent on production. Most nuclear organizations do not yet have targeted programs to assess and improve their security culture.

Learning, testing, peer review, and implementing best practices

In nuclear safety, there is a strong emphasis on learning from incidents, exchange of best practices, peer review, and realistic simulations and exercises to train operators in responding to various problems that may occur.[65] Organizations such as the IAEA and the industry-led World Association of Nuclear Operators (WANO) collect and analyze data on problems arising in operations, near-misses, lessons learned, and best practices, and distribute this information to operators so that they can continually learn from others' experience and improve their safety operations. All nuclear power plants around the world are members of WANO and commit to accepting on-site peer reviews of their safety practices by international teams from WANO. The IAEA also provides peer review services.

Partly because of the pervasive secrecy surrounding nuclear security, very little of this exists for nuclear security. The IAEA does provide international peer reviews of physical protection and other nuclear security arrangements when states request them.[66] But fewer than half of the world's nuclear power reactors, and very few of the sites with HEU or plutonium, have ever had an international review of their security arrangements. No industry organization provides nuclear security peer reviews comparable to the safety peer reviews that WANO provides.

Although the IAEA maintains databases of incidents involving illicit trafficking in nuclear or radioactive materials or malicious acts at nuclear facilities, very few of the reports in these databases have information on how the original thefts or sabotage incident occurred or lessons learned about how similar incidents could be prevented in the future—in stark contrast to relevant safety databases, which focus sharply on lessons learned for preventing similar incidents. No authoritative database of nuclear security-related incidents, root causes, and lessons learned currently exists.

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[65] Nevertheless, substantial problems with nuclear safety continue to arise, even in countries such as the United States and Japan, which have more experience operating nuclear power plants than most other countries. If compared, for example, to airline safety, nuclear safety organizations and investigations are markedly less open and transparent. For a critique of safety approaches in Japan that contributed to the Fukushima disaster, see Yoichi Funabashi and Kay Kitazawa, "Fukushima in review: A complex disaster, a disastrous response," *Bulletin of the Atomic Scientists*, Vol. 68, no. 9 (March 2012); and James M. Acton and Mark Hibbs, *Why Fukushima Was Preventable*, (Washington, D.C.: Carnegie Endowment for International Peace, March 2012). For an assessment of the U.S. Nuclear Regulatory Commission's efforts to learn from the Fukushima crisis, see David Lochbaum and Edward Lyman, *U.S. Nuclear Power Safety One Year After Fukushima* (Cambridge, Mass.: Union of Concerned Scientists, 2012). For a description of issues surrounding an incident in the United States that very nearly led to a large loss of coolant accident, see U.S. Congress, Government Accountability Office, *Nuclear Regulation: NRC Needs to More Aggressively and Comprehensively Resolve Issues Related to the Davis-Besse Nuclear Power Plant's Shutdown,* GAO-04-415 (Washington, D.C.: GAO, May 2004).

[66] On the basis of the information from such reviews, the IAEA can help states develop comprehensive nuclear and radiological security plans, covering everything from protection of radiological sources to improved detection of nuclear and radiological materials covering international borders. When reviews indicate that significant nuclear security investments are needed, the IAEA will work with donor states to arrange help in financing those investments, and, on a limited basis, can provide equipment and other assistance itself as well. International Atomic Energy Agency, *Nuclear Security Report 2011*, GOV/2011/51-GC(55)/21 (Vienna: IAEA, 5 September 2011), http://www.iaea.org/About/Policy/GC/GC55/GC55Documents/English/gc55-21_en.pdf (accessed 3 February 2012).

The World Institute for Nuclear Security (WINS), established in 2008 (just before the four-year effort began), provides a forum for nuclear security operators to discuss and exchange best practices. In a survey, over 85% of the WINS members who responded indicated that they had made changes to their nuclear security practices as a result of what they had learned from WINS activities.[67]

Since the beginning of the four-year initiative, all of these efforts have continued and expanded. The IAEA has carried out 12 International Physical Protection Advisory Service missions since early 2009, roughly continuing the pace of the previous three years, and these have included the first missions in nuclear weapon states (including to Britain's Sellafield site, where over 100 tons of separated plutonium is stored, and to the Graveline power plant in France).[68] The United States will host a mission, probably at the HEU-fueled reactor at the National Institute of Standards and Technology, but this is not likely to occur until 2013-2014. The IAEA's databases have been strengthened and expanded. WINS' best practice efforts have accelerated dramatically. Over the past three years, WINS has held 25 best-practice workshops and published 25 best-practice guides, covering many of the most important areas of nuclear security. WINS' membership has increased to over 900 organizations and individuals, representing some 62 countries.[69]

Training

Nuclear security staff must have appropriate training to do their jobs effectively. Today, most of this training occurs on the job, and few countries have established specific requirements for the knowledge and skills individuals doing particular security-relevant jobs must have.

During the four-year effort, however, a number of significant improvements in nuclear security training have begun or been announced. Countries have announced plans for over a dozen "centers of excellence" that would provide training in nuclear security, including centers in China, Japan, South Korea, Italy, India, and South Africa, among others. Some of these (such as the center in Japan) are already providing training, while others are still in the planning stage.[70] Russia has taken initial steps to strengthen and institutionalize its training centers, in particular establishing new regulatory requirements for a broad range of nuclear-security-related jobs, which should help its training centers support themselves with tuition paid by operating organizations, rather than relying on continued U.S. support. The IAEA and a group of European universities have established a network of institutions working on nuclear security training, which is developing new courses and curricula.[71] To date, there are no agreed standards for or certifications of the effectiveness of nuclear security training; WINS is planning to address this gap with a new certification program.[72]

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[67] Data provided by WINS, March 2012.
[68] Data provided by the IAEA, March 2012.
[69] Data provided by WINS, March 2012. All WINS best-practice guides are available to all WINS members at http://www.wins.org.
[70] The Japanese center, the "Integrated Support Center for Nuclear Nonproliferation and Nuclear Security," opened in 2011. A description of the center and its activities can be found at its website, http://www.jaea.go.jp/04/iscn/index_en.html (accessed 13 March 2012). Major nuclear security training centers have existed in the United States and Russia for years. Interview with U.S. laboratory expert, February 2012.
[71] The International Atomic Energy Agency, *IAEA Nuclear Security Achievements 2002-2011*, (Vienna, Austria: March 2012), http://www.iaea.org/Publications/Booklets/NuclearSecurity/nsachievements0312.pdf (accessed 22 March 2012), p. 13.
[72] Personal communication with Roger Howsley, January 2012.

Beyond Nuclear Security

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 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 and Iran that it is in their national interests to verifiably abandon their pursuit of nuclear weapons—and by making 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 are reducing the risk that al Qaeda could put together and carry through a nuclear bomb project. Indeed, senior Obama administration officials have described the central leadership of al Qaeda (as opposed to its regional affiliates and the loose-knit global movement it spawned) as on the verge of "strategic defeat."[2] But al Qaeda has proved resilient after past low points, and other terrorist groups have pursued nuclear weapons in the past and may do so in the future; while these blows to al Qaeda should be applauded for reducing the near-term risk, there are no grounds for confidence that the long-term danger of nuclear terrorism has past.

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

[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] Elisabeth Bumiller, "Panetta Says Defeat of Al Qaeda Is 'Within Reach,'" *New York Times,* July 9, 2011, http://www.nytimes.com/2011/07/10/world/asia/10military.html (accessed on 7 March 2012).

Next Steps for the Four-Year Effort and Beyond

The assessment in the preceding pages makes clear that the four-year effort to ensure effective security for all the world's nuclear weapons and materials has made the world a safer place. Both the identification of a four-year target and the elevation of the challenge to the highest political levels have helped to focus attention and overcome bureaucratic obstacles.

But in most cases, the progress has been slow by comparison to the scale of the work to be done. At the current pace, it will not be possible to declare in 2013 that all the world's nuclear weapons and weapons-usable nuclear material are effectively and lastingly secured and accounted for.

Beyond Nuclear Security (cont.)

have put in place stronger criminal laws imposing severe penalties for crimes related to nuclear theft, smuggling, and terrorism. The United States is 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. 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 little chance of detecting 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. Yet the Obama administration's budget proposal for the coming fiscal year would drastically reduce funding for the Second Line of Defense effort, making it necessary for the United States to postpone or cancel cooperation on installing radiation detectors with many countries.[4] 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 continue to help countries put radiation detection in place.

[3] "Interpol Creates Nuclear Terrorism Prevention Unit," *Security and Defense Agenda,* 19 May 2011, http://www.securitydefenceagenda.org/Contentnavigation/Library/Libraryoverview/tabid/1299/articleType/ArticleView/articleId/2577/Interpol-creates-nuclear-terrorism-prevention-unit.aspx.

[4] U.S. DOE, *FY 2013 Congressional Budget Request: National Nuclear Security Administration,* pp. 405-410, 426-429.

The work of nuclear security does not have an end date. While it is important to improve nuclear security as much as possible during the four-year effort, the international community will have much to do to improve and sustain nuclear security after 2013. The obstacles to rapid and lasting progress in nuclear security—complacency, bureaucracy, political disputes, and more—are real and difficult to overcome. The four-year effort and the nuclear summit process have begun to chip away at these obstacles—but they remain ever-present barriers. As with nuclear safety, only a culture of continual improvement can sustain nuclear security over the long haul.

In recent years, and particularly during the four-year effort, the focus of nuclear security initiatives

has begun to shift, from providing funding and assistance (particularly from the United States) to convincing countries to upgrade their nuclear security approaches themselves. While the United States and other donor countries should continue to make resources available wherever they are needed to achieve effective nuclear security, the focus should increasingly be on each country with weapons-usable material to provide effective and sustainable security itself. (See "Fulfilling U.S. Commitments," p. 27, for a discussion of as yet unfulfilled U.S. commitments from the 2010 nuclear security summit) Indeed, this is the only approach that has any hope either of achieving major improvements by the end of 2013, or of leading to security that will be sustainable over the decades to come. But convincing countries to put additional security measures in place will inevitably require persuading leaders and policy makers that the threat of nuclear terrorism is real and the measures now in place are insufficient to address it—which many countries do not believe today (a point addressed in more detail below).

The United States and other countries working to improve nuclear security should take a number of steps to address each of the categories of nuclear security efforts discussed in this report—along with broader steps to strengthen global governance of nuclear security for the long haul.

- **Strengthen partnerships with Pakistan and Russia—with a focus on sustainability**. U.S. relations with both Pakistan and Russia have been strained in recent months. These disputes inevitably make cooperation to secure and consolidate nuclear stockpiles more difficult. In both of these very different cases, it is time to begin building a different nuclear security relationship, more genuinely based on real partnership. In Pakistan, to achieve a low risk of nuclear theft will require both continued improvements in nuclear security and steps to stabilize the country and address the drivers of extremism. In Russia, the Nunn-Lugar accord that provides the legal basis for nuclear security cooperation will expire in June 2013, and both sides agree it is time for Russia to shoulder the main burden of financing its nuclear security itself. The two sides should consider a new agreement whose terms are genuinely based on equality (as is the case with the civilian nuclear cooperation agreement), and which would provide a legal basis not only for nuclear security work but for a range of other projects that could serve both sides' interests, from developing new procedures for verifying nuclear arms reductions to joint development of new counterterrorism technologies. Russia should commit to consolidating its nuclear weapons, HEU, and plutonium to the minimum necessary number of locations, and to providing sufficient funding so that all sites have the resources to implement and sustain effective nuclear security and accounting systems—and the United States should pursue that objective in high-level discussions. Ultimately, the United States and Russia, as the countries with some 95% of the world's nuclear weapons and a large fraction of the world's HEU and separated plutonium, must each take a leadership role. This effort should be framed in part as an essential enabler of Russia's strategic goal of nuclear energy growth.[73]
- **Expand the 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. As a top priority, the U.S. government and other interested governments should continue to use sub-

[73] See: Project on Managing the Atom and Russian Research Center "Kurchatov Institute," *Promoting Safe, Secure, and Peaceful Growth of Nuclear Energy: Next Steps for Russia and the United States* (Cambridge, Mass.: Report for Belfer Center for Science and International Affairs, Harvard Kennedy School, October 2010) http://belfercenter.ksg.harvard.edu/files/Promoting-Safe-Secure-and-Peaceful-Growth-of-Nuclear-Energy.pdf (accessed 7 March 2012).

Fulfilling U.S. Commitments

At the first nuclear security summit, the United States made a broad range of commitments. Some of the most important of these commitments have not yet been fulfilled. As the United States seeks to lead a global effort to improve nuclear security, it is important for the United States to lead by example by undertaking substantial commitments and fulfilling them.

IAEA nuclear security review. The United States committed to invite an IAEA-led International Physical Protection Advisory Service (IPPAS) review of security at the HEU-fueled reactor at the National Institute of Standards and Technology (NIST). Although IPPAS reviews that Britain and France committed to have already been completed, the United States did not submit a formal request for a review until March 2012, just before the Seoul summit.[1] Britain's review was not at a small research reactor but at the Sellafield nuclear site, where more than 100 tons of separated plutonium are stored—by far the most sensitive site the IPPAS program has ever reviewed. The United States should move forward with its planned IPPAS review and invite an additional review at a major nuclear site such as the Savannah River Site (where IAEA inspectors already monitor plutonium in storage).

Ratification of conventions. At the 2010 summit, the United States committed to expedite the process of ratifying the 2005 amendment to the physical protection convention and the nuclear terrorism convention. Although the Obama administration has proposed implementing legislation, Congress has not acted on it and the United States has not ratified either treaty.

Converting reactors. At the 2010 summit, the United States pledged to convert its six remaining civilian HEU-fueled research reactors to LEU when appropriate fuels became available. Fuel development has since been delayed by budget cuts, and conversion of some of these reactors may now be as much as a decade away.

Budgets for nuclear security. At the 2010 summit, the United States announced that it planned the largest nuclear security budget ever for 2011. While the fiscal year 2011 nuclear security request was the largest ever, not all of it was approved by Congress, and the fiscal year 2012 budget was less ambitious. The Obama administration's proposed budgets for fiscal year 2013 would cut HEU-removal efforts by more than 15 percent compared to fiscal year 2012 and would drastically reduce programs to help countries around the world install radiation detectors.[2]

The United States made a range of other commitments that have been fulfilled. But it is time for the United States to make new, far-reaching commitments to nuclear security, and to follow through in implementing them.

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[1] Data provided by National Security Council and IAEA officials, March 2012.

[2] U.S. Department of Energy, *FY 2013 Congressional Budget Request: National Nuclear Security Administration*, p. 463 and p. 405. Budget projections for FY2013-FY2016 for the Global Threat Reduction Initiative were cut by half a billion dollars compared to projections made the previous year. See Bunn and Harrell, *Consolidation: Thwarting Nuclear Theft*. The proposed cut in the FY2013 budget for removing Russian-origin HEU was projected the previous year, and appears to reflect a lull in planned removal activity (projected at 88 kilograms of Russian-origin HEU in FY2013 compared to 291 kilograms the previous year, and an average of 115 kilograms a year in the four years following FY2013). The drastic proposed cut in Second Line of Defense funding appears to reflect a judgment that many of the most important sites for installation of radiation detectors had been completed, and the program should focus on sustainability of what has already been installed and deployment of a small number of mobile detectors, while reevaluating its longer-term strategy. U.S. Department of Energy, *FY 2013 Congressional Budget Request: National Nuclear Security Administration*, p. 9 and p. 470.

stantial packages of incentives, shaped for the needs in each case, to convince countries to eliminate civilian sites with hundreds of kilograms or tons of high-quality HEU. At the same time, the United States, Russia, and other interested states should work together to shrink the number of locations where nuclear weapons and military stocks of plutonium and HEU continue to exist, and to limit the number of sites with civilian plutonium as well.[74]

- **Focus on effective national nuclear security rules.** The United States and other interested governments should work with countries around the world to ensure that they put in place effective and well-enforced regulations requiring facilities and transporters with nuclear weapons, HEU, or separated plutonium to conform to a minimum security standard. That standard should require facilities to protect against *at least* a) a modest group of well-armed and well-trained outsiders; b) a well-placed insider; and c) both outsiders and an insider working together, using a broad range of possible tactics. Countries facing more capable adversaries should provide higher levels of protection. Such rules would not only reduce the risk of nuclear theft; they would create a strong incentive to consolidate stocks at fewer locations as a means of reducing the costs of nuclear security. One approach, for example, would be for a group of countries committed to nuclear security to make a political commitment to meet high standards of nuclear security (identifying a series of specifics), and to develop measures to give each other confidence these agreed steps were being taken; these countries could then invite other countries to join them in this commitment, and offer to assist any country that needed help meeting those standards.
- **Secure 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 insider theft.
- **Enhance efforts to strengthen security culture and implement best practices.** Building organizational cultures in which all staff 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. The United States and other interested governments should seek to ensure that each facility and transporter handling nuclear weapons, HEU, or separated plutonium has a program in place to assess and strengthen its security culture, and is participating in best-practice exchanges.
- **Build new approaches to nuclear security governance.** The current set of agreements and institutions related to nuclear security needs to be strengthened. The current framework sets no specific standards for how secure nuclear weapons and materials should be; provides no regular means for verification, transparency, or other measures to build confidence that states are fulfilling their nuclear security obligations; and, after the nuclear security summits come to an end, includes no mechanisms for high-level discussions of the next steps that should be taken. If, in fact, the 2014 nuclear security summit is to be the last such meeting, states around the world must find a way to institutionalize some other approach to the global discussion of nuclear security.

[74] Bunn and Harrell, *Consolidation: Thwarting Nuclear Theft*.

Past experience suggests that states are not willing to agree to specific, binding nuclear security standards, or to go beyond the approach of having the IAEA Office of Nuclear Security organize nuclear security peer reviews only when states voluntarily request them. The United States and other interested countries should work to develop more informal and adaptable nuclear security governance approaches. On a broader level, to build confidence and identify issues to be addressed, countries could 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. Biannual ministerial-level meetings after the final security summit might also provide a focus for discussing additional steps to improve nuclear security.[75]

Combating Complacency

Countries will only agree to take action if they believe such steps are needed, and can be accomplished at modest cost and modest interference with national sovereignty. As mentioned above, the key to improving nuclear security and preventing nuclear terrorism is to convince political leaders and nuclear managers around the world that nuclear terrorism is a real and urgent threat to *their* countries' security, worthy of a significant investment of their time and money, and that improvements on their part are necessary to reduce the risk. The nuclear security summit process and the Global Initiative to Combat Nuclear Terrorism have begun to build a sense of urgency. But much more needs to be done.

There are three layers of complacency that must be overcome: (1) the belief that terrorists could not plausibly make a bomb; (2) the belief that nuclear security measures are already adequate, so that terrorists could not plausibly get the materials needed for a bomb; and (3) the belief that even if terrorists could get nuclear material and could make a crude bomb, it is the United States' problem, not a problem other countries need to worry about very much. President Obama should work with other countries to take several steps to overcome this complacency and build the needed sense of urgency and commitment, including:[76]

- **Joint threat briefings and assessments.** Upcoming summits and other high-level meetings with key countries should include detailed briefings for leaders on the nuclear terrorism threat, given jointly by experts from the country concerned together with outside experts as a means of avoiding whitewashing. These would highlight the possibility that terrorists could get nuclear material and make a nuclear bomb, the global economic and political effects of a terrorist nuclear attack, and steps that could be taken to reduce the risk. U.S. briefings for U.S. and Russian officials highlighting intelligence on continuing nuclear security vulnerabilities were a critical part of putting together the Bush-Putin Bratislava nuclear security initiative. With some key countries, the United States should seek agreement to draft joint assessments of the threat, following on the 2011 non-government U.S.-Russian assessment.[77]

[75] For a different set of suggestions on nuclear security governance, see, for example, Luongo, "Nuclear Security Governance for the 21st Century."

[76] The following section is adapted from Matthew Bunn, *Securing the Bomb 2010: Securing all Nuclear Materials in Four Years* (Cambridge, MA: Project on Managing the Atom, Harvard University, and Nuclear Threat Initiative 2010); http://www.nti.org/securingthebomb.

[77] Matthew Bunn, Yuri Morozov, Rolf Mowatt-Larrsen, Simon Saradzhyan, William Tobey, Viktor I. Yesin, and Pavel S.

- **Intelligence-agency discussions.** In most countries, the political leadership gets much of its information about national security threats from its intelligence agencies. Intelligence professionals must actively work with their counterparts in other countries to build understanding of the threat and cooperation against it.[78]
- **The "Armageddon Test."** President Obama should direct U.S. 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; in others, 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.[79]
- **Nuclear terrorism exercises.** Building on the exercise program that has begun in the Global Initiative to Combat Nuclear Terrorism, the United States and other leading countries should organize a series of exercises with senior policymakers from key states. These exercises should have scenarios focused on theft of nuclear material, the realistic possibility that terrorists could construct a crude nuclear bomb if they got enough HEU or plutonium, just how difficult it would be to stop them once they had the material, and how much *all* countries would be affected if a terrorist nuclear bomb went off.[80] Participating in a realistic exercise can reach officials emotionally in a way that briefings and policy memos cannot. A program of such exercises should become a central element of the Global Initiative.
- **Fast-paced nuclear security reviews.** The United States and other leading countries should encourage leaders of key states to pick teams of security experts they trust to conduct fast-paced, "stress test" reviews of nuclear security in their countries, assessing whether facilities are adequately protected against a set of clearly-defined threats—such as a well-placed insider, or two teams of well-armed, well-trained attackers. (In the United States, such fast-paced reviews after major incidents such as 9/11 have often revealed a wide range of vulnerabilities that needed to be fixed.)

Zolotarev, *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 U.S. and Canadian Studies, June 2011).

[78] We are grateful to Rolf Mowatt-Larssen for discussions of this approach.

[79] This concept was originally developed by Rolf Mowatt-Larssen. Care would have to be taken to structure the effort in a way that avoided creating perceptions of a market for nuclear material that might contribute to additional nuclear thefts. See William H. Tobey and Rolf Mowatt-Larssen, "The Armageddon Test: To Prevent Nuclear Terrorism, Follow the Uranium," (Cambridge, MA Project on Managing the Atom, Harvard University, 26 July 2010), http://belfercenter.ksg.harvard.edu/publication/20279/ (accessed 22 March 2012).

[80] The model would be the "Black Dawn" exercise organized by the Center for Strategic and International Studies (and sponsored by the Nuclear Threat Initiative) for key NATO officials. For a description, see *Black Dawn: Scenario-Based Exercise* (Washington, D.C.: Center for Strategic and International Studies, 2004), available at http://www.csis.org/media/csis/pubs/040503_blackdawn.pdf (accessed 25 February 2012).

- **Realistic testing of nuclear security performance.** The United States and other leading countries should work with key states around the world to implement programs to conduct realistic tests of nuclear security systems' ability to defeat either insiders or outsiders. (Failures in such tests can be powerful evidence to senior policymakers that nuclear security needs improvement.)
- **Shared databases of threats and incidents.** The United States and other key countries should collaborate to create shared databases of unclassified information on actual security incidents (both at nuclear sites and at non-nuclear guarded facilities) that offer lessons for policymakers and facility managers who are considering nuclear security levels and particular threats to defend against. The World Institute for Nuclear Security (WINS) could be a forum for creating one version of such a threat-incident database. In the case of safety, rather than security, reactor operators report each safety-related incident to groups such as the Institute of Nuclear Power Operations (the U.S. branch of the World Association of Nuclear Operators), and these groups analyze the incidents and distribute lessons learned about how to prevent similar incidents in the future to each member facility—and then carry out peer reviews to assess how well each facility has implemented the lessons learned.[81]

In spite of the formidable obstacles, the international community can achieve the goal of effectively and lastingly protecting all stocks of nuclear weapons, HEU, and plutonium, so that they never fall into the hands of terrorists. Doing so requires sustained high-level leadership, a sensible strategy, partnership-based approaches, adequate resources, and good information. The actions President Obama and other world leaders have already taken have led to real progress and opened new opportunities. Countries need to seize those opportunities and build a world in which there is virtually no chance that terrorists could acquire the means to build a nuclear bomb.

[81] See Joseph V. Rees, *Hostages of Each Other: The Transformation of Nuclear Safety since Three Mile Island* (Chicago: University of Chicago Press, 1994).

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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