# 3 TRACKING PROGRESS IN CONTROLLING NUCLEAR WARHEADS, MATERIALS, AND EXPERTISE

The United States, other countries, and the International Atomic Energy Agency (IAEA) have a wide range of efforts under way to secure, monitor, and reduce stockpiles of nuclear weapons and materials in the former Soviet Union and around the world. In this chapter we use a series of specific metrics to assess in detail the progress U.S.-funded programs are making in each of six areas: securing nuclear warheads and materials; interdicting nuclear smuggling; stabilizing employment for nuclear personnel; monitoring nuclear stockpiles; ending further production; and reducing nuclear stockpiles.

This review demonstrates that the efforts by the United States and its global partners to reduce the threat of nuclear terrorism have had real, demonstrable successes, representing an excellent investment in American and world security. Enough nuclear material for thousands of nuclear weapons has been permanently destroyed. (Indeed, nearly half of the nuclear-generated electricity in the United States comes from blended-down highly enriched uranium (HEU) from dismantled Russian nuclear weapons, as part of the U.S.-Russian HEU Purchase Agreement, sometimes known as "Megatons to Megawatts.") Security for scores of vulnerable nuclear sites has been demonstrably improved, and the United States and Russia have now set a joint objective of completing security and accounting upgrades for most nuclear warhead and weapons-usable nuclear material sites in Russia by the end of 2008. At least temporary civilian employment has been provided for thousands of nuclear weapons scientists and workers who might otherwise have been driven by desperation to seek to sell their knowledge or the materials to which they had access.

But as we rightly celebrate this important progress—and the hard work by hundreds of U.S., Russian, and international officials and experts that brought it about—it is important to remain focused on the parts of the job yet to be done. As we discuss in detail below, by the end of fiscal year (FY) 2005, U.S.-funded security upgrades had been completed for roughly 54% of the buildings containing weapons-usable nuclear material in the former Soviet Union.[1] Less than a quarter of Russia's stockpile of bomb uranium has been destroyed, and it will still be years before destruction of substantial quantities of U.S. and Russian excess bomb plutonium even begins. Much less than half of Russia's excess nuclear weapons experts have yet received self-supporting civilian jobs (as opposed to short-term subsidized grants). Beyond the former Soviet Union, cooperative security upgrades are only just beginning, leaving many sites dangerously vulnerable, and no effective, binding global nuclear security standards have yet been put in place.

Moreover, some of the most important issues to be addressed are difficult to reflect in quantifiable metrics. As discussed in the previous chapter, in Russia, even as the agreed upgrades near completion, important questions remain about whether the security levels being achieved by those upgrades are enough to meet the threats that exist in Russia; whether those

[1] The U.S. federal fiscal year runs from 1 October to 30 September of the year named, so FY 2005 is the fiscal year that ended on 30 September 2005.

security levels will be sustained after U.S. assistance phases out; and whether strong security cultures are being built. Similar issues are sure to arise in other countries as cooperation beyond the former Soviet Union expands. In short, the goal of ensuring that every stockpile of nuclear warheads and materials worldwide is sustainably secured and accounted for to stringent standards remains a long way away—unacceptably far away, given the urgency of the threat.

It is impossible to directly measure the risk of nuclear theft and terrorism, and whether it is increasing or decreasing. Hence, all the measures of progress the U.S. government uses to track these efforts, and all the measures we discuss in this chapter, are intended only as partial substitutes for such a direct measure, reflecting progress in implementing some particular approach to addressing one part of this multi-faceted problem. The metrics used here are inevitably rough summaries of a more complex story.

We have relied on official government measures and data where possible, but in some cases these are not available. The administration, led by the Department of Energy (DOE), has improved the availability and transparency of measures of performance for its programs to control nuclear warheads, materials, and expertise worldwide.[2] But the fact remains that the U.S. government has no comprehensive plan for ensuring that *all* nuclear weapons and weapons-usable materials worldwide are secure and accounted for, or for the other elements of this agenda, and has not put forward a comprehensive set of milestones that would allow Congress and the public to fully understand both how much progress is being made and where prolonged delays suggest the need for a change in approach.[3] Until that occurs, we will continue to provide the best measurable assessments we can from outside the government.

Such measures to track progress are crucial to the effectiveness of almost any government program. Only by understanding which efforts are showing real results and which efforts are not can mid-course corrections be made, and ineffective efforts be improved. But such measures are inevitably imperfect. Undue reliance on particular progress metrics can be misleading. Progress on sustainability and security culture, for example, is fundamental to the long-term success of nuclear security efforts, but such prog-

[2] The detailed justifications of their budget proposal supplied by the agencies to Congress contain performance information and targets for each major activity; for instance, see U.S. Department of Energy, *FY 2007 Congressional Budget Request: National Nuclear Security Administration--Defense Nuclear Nonproliferation*, vol. 1, DOE/CF-002 (Washington, D.C.: DOE, 2006; available at http://www.cfo.doe.gov/budget/07budget/Content/Volumes/Vol_1_NNSA.pdf as of 24 February 2006). See also the performance assessments of the Energy and State Departments: U.S. Department of Energy, *Performance and Accountability Report: FY 2005* (Washington, D.C.: DOE, 2006; available at http://www.cfo.doe.gov/progliaison/2005pr.pdf as of 4 April 2006); U.S. Department of State and U.S. Agency for International Development, “Strategic Goal 4: Weapons of Mass Destruction” in *FY 2007 Performance Summary* (Washington, D.C.: U.S. Department of State, 2006; available at http://www.state.gov/documents/organization/59174.pdf as of 14 April 2006). A handful of relevant programs have been examined using the White House Office of Management and Budget’s Program Assessment Rating Tool (PART): see U.S. Office of Management and Budget, *Program Assessment Rating Tool* (Washington, D.C.: OMB, 2006; available at http://www.whitehouse.gov/omb/expectmore/ as of 27 March 2006)

[3] For a discussion on the absence of a government-wide strategic plan, see U.S. Congress, Government Accountability Office, *Weapons of Mass Destruction: Nonproliferation Programs Need Better Integration*, GAO-05-157 (Washington, D.C.: GAO, 2005; available at http://www.gao.gov/new.items/d05157.pdf as of 31 January 2006), pp. 8-17.

ress is very difficult to quantify, and is not reflected at all in the measures presented in this chapter. Any particular measure of progress reflects one definition of the problem to be addressed, and one idea of the best method for solving that problem, excluding others. A manager focused exclusively on racking up more progress by that measure is likely to miss opportunities for different approaches to taking on the problem—and thus managing to a particular metric can breed complacency.

## Tracking Progress: Securing Nuclear Warheads and Materials

The overall goal in this category is simple: every nuclear weapon and every kilogram of nuclear material anywhere in the world must be sustainably secured and accounted for, to standards sufficient to defeat the threats that terrorists and criminals have shown they can pose. As noted in the last chapter, this is a global problem, with weapons-usable nuclear materials in some 40 countries under widely varying levels of security.

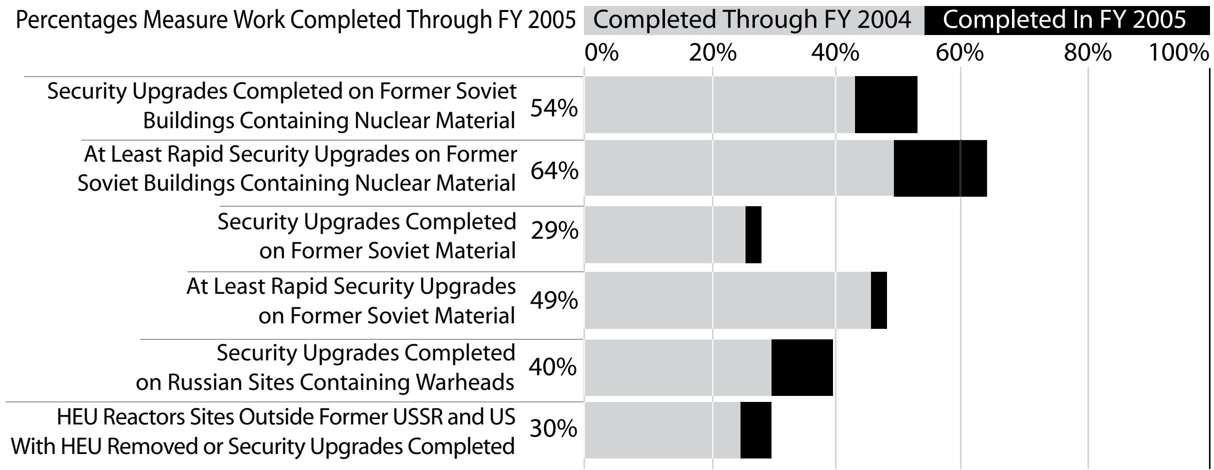
Assessing how close the world is to meeting the goal of effective security for these stockpiles is more difficult than it might seem. Within the former Soviet Union, the U.S. government has made available reasonably detailed estimates of the number of sites and buildings with weapons-usable nuclear materials and the quantity of these materials, along with estimates of the percentages of these sites, buildings, and materials covered by various levels of upgrades; data on warhead sites and upgrades are numerous, though far less complete. But for the rest of the world, there are very few publicly available data on the number of sites where nuclear warheads and the materials needed to make them exist, the current security levels at those sites compared to the threats that terrorists and criminals have shown they can pose in the regions of those facilities, or the quantity and quality of weapons-usable material that exists at those sites. Data have simply not been collected—in classified form or not—on important matters such as pay, morale, and corruption among the staff at nuclear sites around the world, or what procedures are used at different facilities to assess and test the security of sites and what the results of those assessments may have been.

In particular, the answer to the basic policy questions "how many buildings around the world need security upgrades, how extensive are the upgrades they need, how much will that cost, and how long will that take?" depend a great deal on what standards of nuclear security are set as the objective of the effort. Currently, the standards being pursued vary widely from one program to another, for reasons that are more the result of historical accident than rational calculation. The United States is spending roughly $1.5 billion annually on safeguards and security for DOE facilities and activities,[4] most of which goes to protecting sites against a very substantial post–9/11 design basis threat (DBT) that reportedly includes squad-sized teams of well-trained outside attackers equipped with sophisticated armaments and equipment, along with multiple well-placed insiders.[5]

[4] See the "Safeguards and Security Crosscut" in U.S. Department of Energy, *FY 2007 Congressional Budget Request: Other Defense Activities*, vol. 2, DOE/CF-003 (Washington, D.C.: DOE, 2006; available at http://www.cfo.doe.gov/budget/07budget/Content/Volumes/Vol_2_ODA.pdf as of 5 May 2006).

[5] For a discussion of the kinds of armament and equipment included in the new DOE DBT, see Ronald E. Timm, *Security Assessment Report for Plutonium Transport in France* (Paris: Greenpeace International, 2005; available at http://greenpeace.datapps.com/stop-plutonium/en/TimmReportV5.pdf as of 6 February 2006). For non-government

***Figure 3-1***
***How Much Securing Work Have U.S.-Funded Programs Completed?***




U.S.-sponsored upgrades being installed in Russia are intended to defend against more modest threats (though apparently the threats U.S. teams are directed to help Russian facilities defend against have been increased since 9/11). In principle Russian sites should be defended against higher threats than U.S. sites, rather than the other way around, as both the outsider and insider threats in Russia appear to be substantially higher than they are in the United States, given the ongoing terrorist conflict there and the huge problem of insider theft and corruption bedeviling Russian society. For HEU-fueled research reactors in other countries, the United States is only helping with upgrades to meet very general and vague IAEA recommendations, which do not include *any* particular threat to be defended against; in most cases, sites "completed" under this effort could probably only defend against a very small number of outside attackers and perhaps one insider.

Clearly, how many sites are below the bar of effective nuclear security, by how far, depends on where the bar is set. If the objective was to ensure that all nuclear weapons and weapons-usable nuclear material worldwide were secured to DOE standards, a very large fraction of all the world's nuclear facilities would probably require upgrades, and the upgrades needed would likely be extensive, costly, and time-consuming (as they are expected to be at DOE's own facilities, which are still putting in place the measures needed to defeat the post–9/11 threats DOE regulations require them to be prepared for). On the other hand, DOE's Global Threat Reduction Initiative (GTRI) program believes that the vast majority of the world's HEU-fueled research reactors already have security in place that meets International Atomic Energy Agency (IAEA) recommendations, leaving only about 10 HEU-fueled research reactors worldwide where security upgrades are still underway or planned, and 17 more where the

summaries of the size of the potential attacking forces included in the threat, see, for example, Project on Government Oversight, "Energy Ups Their DBT, NRC Still Making Excuses" (Washington, D.C.: POGO, 2004; available at http://pogoblog.typepad.com/pogo/2004/09/energy_ups_thei.html as of 5 February 2006); Peter Stockton, "Vulnerability of Spent Fuel Pools and the Design Basis Threat" (Washington, D.C.: Project on Government Oversight, 2004; available at http://pogo.org/m/ep/ep-spentfuelpools-NAS-5102004.pdf as of 1 February 2006).

U.S. government is still assessing the need for upgrades.[6]

We believe that the bar should be set at a level that will provide security able to defeat the kinds of overt attacks and covert thefts that terrorists and criminals have shown they can carry out in different regions of the world. United Nations Security Council Resolution 1540 legally requires all states to have "appropriate effective" security for whatever stockpiles of nuclear weapons and weapons-usable nuclear materials they may have. If the word "effective" is taken literally, it suggests that these security measures must be able to effectively defeat the threats that have been shown to exist. This suggests a security standard that would probably be well above the minimum measures needed to meet current IAEA recommendations, though perhaps below the standard now required of DOE facilities. We do not yet have good measures of how many facilities worldwide would require what level of upgrade to meet such an objective. We believe Congress should consider asking the administration to prepare estimates of how many facilities worldwide would require upgrades, and how extensive those upgrades would be, for various possible standards of nuclear security, and to make a recommendation to Congress as to what nuclear security standards should be pursued. In the absence of such specific measures of the total amount of global work to be done, we use, in this chapter, a number of measures focused on Russia, followed by a very partial measure of the global picture.

In the absence of hard data on the real effectiveness of nuclear security systems in the former Soviet Union and around the world, we rely, in this section, on metrics very similar (in most cases) to those the U.S. government uses to report the progress of its efforts in these areas. These focus, in particular, on (a) materials or buildings that have two defined levels of security and accounting equipment upgrades installed with U.S. assistance—"rapid" upgrades and "comprehensive" upgrades—and (b) buildings or sites where the potential nuclear bomb material has been removed entirely, eliminating the theft risk from that location.[7]

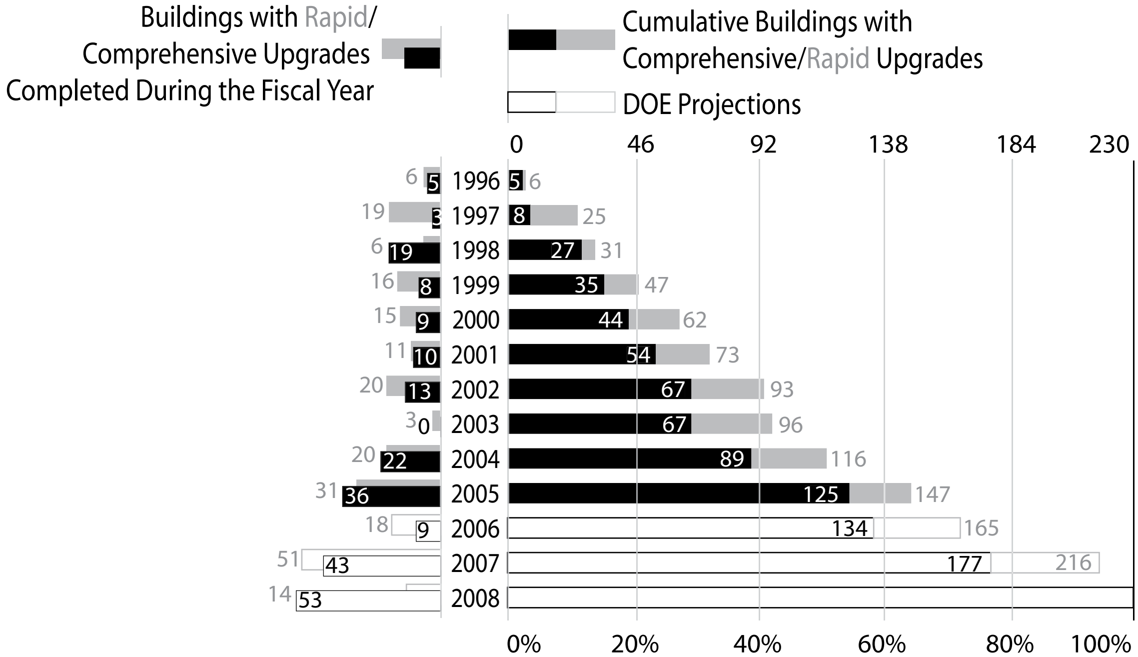
By its nature, however, the first category of measure does not include the progress Russia or other partner states have made in upgrading security on their own, without U.S. or other foreign assistance. Nor does it include harder-to-measure but crucial progress in areas such as providing training or strengthening independent regulation of nuclear security and accounting, areas which presumably have benefits for securing and accounting for *all* nuclear materials in recipient countries, not just those for which U.S.-funded equipment is being installed. Another key issue is that it measures, essentially, the installation of modern security and accounting equipment, but does not capture whether the *people* at these sites are following effective security procedures and using the equipment in a way that in fact provides high levels of security.[8] Hence,

[6] DOE statement provided to Rep. Robert Andrews (D-NJ), April 2006.

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

[8] For an extensive recent discussion of the importance of the "human factor" in security, in Russia in particular, see Igor Khripunov and James Holmes, eds., *Nuclear Security Culture: The Case of Russia* (Athens, Georgia: Center for International Trade and Security, The University of Georgia, 2004;

**_Figure 3-2_**
**_Annual and Cumulative Number of Buildings with Rapid and Comprehensive Cooperative Security Upgrades Completed_**




it is quite possible for some material counted as "completed" by this measure to be insecure. It is equally possible for material counted as "not completed" to be secure, because the partner state has already taken action to secure it effectively.

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

The best available measure—though still a rough one—of both the fraction of the needed security upgrade work that has been finished and of the fraction of the threat that has been reduced is the fraction of the buildings where weapons-usable nuclear material is located whose security has been upgraded.[9] The fraction of buildings covered is a better measure of risk reduction than the fraction of materials covered because, as DOE puts it, "a building with 1 ton of nuclear material in storage is as great a threat as a building with 10 tons."[10] Improving security at a building with a massive amount of nuclear material involves more work, but not dramatically more, so the total amount of work completed is also more closely related to the number of buildings covered than to the amount of material covered. Building-level data are also better than site-level data, because a large site with dozens of buildings containing nuclear material may have dozens of different groups that

available at http://www.uga.edu/cits/documents/pdf/Security%20Culture%20Report%2020041118.pdf as of 18 February 2006).

[9] We have relied primarily on measures focusing on materials in the past only because these were the only data DOE made publicly available.

[10] U.S. Department of Energy, *FY 2007 Congressional Budget Request: National Nuclear Security Administration--Defense Nuclear Nonproliferation*, p. 514.

have access to that material, and because the work of improving security at such a huge and multifaceted site is much more time-consuming, complex, and expensive than the work of improving security at a small site with only one building.

DOE has now adopted the buildings measure as its primary metric of how much has been accomplished in the cooperative security upgrades program. For a building to be listed as "completed" means that either comprehensive upgrades have been finished there, or DOE has determined that only rapid upgrades were needed at that building (if, for example, the material in the building was of low attractiveness for use in a nuclear weapon). DOE also frequently uses the term "secured," which is used to mean buildings with at least rapid upgrades put in place, regardless of whether DOE still plans to install comprehensive upgrades.

As of the end of FY 2005, just over 54% of the 230 buildings in the former Soviet Union containing weapons-usable nuclear material have had comprehensive security upgrades.[11] By that time, at least rapid security upgrades had been put in place on 64% of the buildings.[12] Figure 3-1 shows the number of buildings with comprehensive or rapid upgrades completed as a fraction of the total amount of buildings requiring upgrades.

**Rate of progress.** During FY 2005, comprehensive upgrades were completed for an additional 36 buildings, almost twice the highest number that had been completed in any previous year, bringing the total completed to 125.[13] Rapid upgrades were completed for an additional 31 buildings, bringing the total from 116 (50%) to 147 (64%)—again the fastest pace of any year since the effort's inception.[14] Figure 3-2 shows the year-by-year progress of comprehensive and rapid security upgrades in the former Soviet Union, and DOE's projections for the remaining years until the effort is complete.[15]

[11] In some cases, upgrades are being performed on buildings without nuclear material, but which are essential to ensuring that nuclear material is secured, such as central alarm stations. The figures in the text are from unpublished data provided by DOE, May 2006.

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

[13] Data provided by DOE, May 2006.

[14] Data provided by DOE, May 2006. These data appear to represent updates to the estimates presented in U.S. Department of Energy, *FY 2007 Defense Nuclear Nonproliferation Budget Request*, p. 514. There, DOE bases its estimates on 195 buildings to be completed by the end of 2008, rather than the more recent 230-building figure, and reports that 150 of these had at least rapid upgrades completed by the end of FY 2005, rather than the more recent 147 figure provided here. The increased number of total buildings in the more recent data significantly reduces the figures for the percentage completed; the figure is 77% of the buildings with at least rapid upgrades for the earlier data in the budget justifications, but 64% here.

Last year, we estimated that 56% of the buildings had at least rapid upgrades completed, compared to the 50% DOE now reports for the end of FY 2004. We built our estimate using data that at the time commingled buildings containing only material with those containing warheads. In those data, there were 205 buildings with weapons-usable material, as opposed to 230 such buildings in the more recent DOE data, or 195 reported in the budget justifications. Such re-estimates are normal as a program gains more data about the scope of work it faces. We should have also been more explicit in last year's report in describing our 56% figure as being the buildings where at least rapid upgrades had been completed, rather than suggesting that all upgrades had been finished at those buildings. For last year's full discussion, see Matthew Bunn and Anthony Wier, *Securing the Bomb 2005: The New Global Imperatives* (Cambridge, Mass., and Washington, D.C.: Project on Managing the Atom, Harvard University, and Nuclear Threat Initiative, 2005; available at http://www.nti.org/e_research/report_cnwmupdate2005.pdf as of 6 June 2006), pp. 32-34.

[15] Data provided by DOE, May 2006.

DOE plans to complete comprehensive upgrades on the buildings with weapons-usable material in Russia by the end of 2008. DOE then expects a four-year period of cooperation to ensure sustainability, during which U.S. assistance will phase down, and Russia's investments, DOE hopes, will increase. Congress has mandated that DOE attempt to put in place a security system in Russia that is sustained with only Russian resources by January 1, 2013.[16]

If the FY 2005 pace of completing buildings could be sustained, the target of completing the planned upgrades by the end of 2008 would be met.[17] Meeting that target, however, will be challenging, and is likely to require sustained leadership on both sides to overcome obstacles to progress as they arise.

In particular, meeting the 2008 target would require rapidly resolving the impasse over access at sensitive sites (or other measures to assure that U.S. taxpayer funds would be spent appropriately) that has so far blocked work on upgrades at Russia's two remaining nuclear warhead assembly and disassembly facilities (known in Russia as the "serial production enterprises"), where a quarter or more of the nuclear material in Russia is thought to reside. These facilities are the most sensitive sites in Russia's nuclear weapons complex, and presumably are already among the most secure sites in Russia. On the other hand, at every site U.S. experts have visited so far, they have quickly reached agreement with Russian security experts that a wide range of security and accounting improvements were needed. Following the 2005 Bush-Putin summit in Bratislava, DOE and Rosatom agreed on a comprehensive joint action plan for completing security upgrades by the end of 2008.[18] But that agreed plan does not yet include these two facilities. Some Russian officials have publicly said that Russia will never agree to implement U.S.-funded upgrades at these sites, but U.S.-Russian discussions of the issue are still ongoing.[19] If DOE's full target for the end of 2008 is to be met, agreement on these sites will have to be reached very quickly, and the work will have to be carried out extremely efficiently. Alternatively, if it proves impossible to work out arrangements with Russia to perform cooperative upgrades at the last two facilities, DOE may choose to declare the job complete when the facilities that have been agreed are finished.

It is important to understand what else the 2008 target does and does not include. Beyond the two serial production enterprises just discussed, there are a very small number of other facilities in Russia which may have weapons-usable nuclear material, but where this has not been confirmed.[20] Until recently, in most

[16] U.S. House of Representatives, *National Defense Authorization Act for Fiscal Year 2003*, 108th Congress, 2nd Session, Public Law 107-314 (2002; available at http://thomas.loc.gov/cgi-bin/query/z?c107:H.R.4546.ENR: as of 16 May 2006).

[17] Completing comprehensive upgrades for the remaining 105 buildings where they have not been completed in three years would require completing 35 per year, compared to the 36 completed in FY 2005. DOE projects a significantly slower pace for FY 2006, followed by 43 buildings in FY 2007 and 53 in FY 2008. Data provided by DOE, May 2006.

[18] U.S. Department of Energy, *FY 2007 Defense Nuclear Nonproliferation Budget Request*, p. 511.

[19] Carla Anne Robbins and Alan Cullison, "Closed Doors: In Russia, Securing Its Nuclear Arsenal Is an Uphill Battle," *The Wall Street Journal*, 26 September 2005.

[20] Committee on Indigenization of Programs to Prevent Leakage of Plutonium and Highly Enriched Uranium from Russian Facilities, Office for Central Europe and Eurasia, National Research Council, *Strengthening Long-Term Nuclear Security: Protecting Weapon-Usable Material in Russia* (Washington,

cases U.S.-funded programs were not sponsoring security upgrades for irradiated HEU, which in many cases still poses a serious proliferation threat, as it is often still highly enriched and not radioactive enough to pose a serious barrier to theft;[21] DOE is now reassessing what upgrades may be needed for some of this material, but those upgrades are not likely to be completed by the end of 2008.[22] Finally, at several sites new or greatly modified storage facilities are being built, and the plan is to move material from other buildings into these facilities; in some of these cases, the building will be finished by the end of 2008, but it will take a substantial period thereafter to move the material—so that material will not yet have improved security as of the end of 2008.[23]

### *Securing Metric 2: Security Upgrades on Former Soviet Nuclear Material*

**Fraction accomplished.** U.S.-funded cooperative nuclear security upgrade efforts concentrated first on upgrading particularly vulnerable sites with small quantities of nuclear material—though still enough for a bomb, if stolen. While completing security upgrades at these sites reduced proliferation risks substantially, it had little effect on the fraction of the total nuclear material covered by upgrades. As a result, the fraction of material covered by different levels of upgrades remains substantially lower than the fraction of buildings with those upgrade levels.

Within the former Soviet Union, as of the end of FY 2005, an estimated 29% of the potentially vulnerable weapons-usable nuclear material outside of nuclear weapons—estimated to amount to roughly 600 tons—had U.S.-funded comprehensive security and accounting upgrades installed.[24] An additional 20% of the material had initial "rapid" upgrades installed, for a total of 49% with either rapid or comprehensive U.S.-funded upgrades completed.[25] Upgrades are underway on a significant additional amount of material. Figure 3-1 shows the amount of material with comprehensive or rapid upgrades completed as a fraction of the total amount of potentially vulnerable nuclear material.

The apparent precision in these figures is illusory. DOE knows exactly which buildings have had what types of security upgrades installed. But in most cases Russia does not provide data on exactly how much material is in each building, for security reasons, and DOE is forced to estimate how much material has been covered by the upgrades at the various buildings where it has worked. (The amount of material in a particular building can fluctuate substantially, as work with this material leads it to be moved around within a site or shipped to other sites.) Indeed, the DOE estimate of 600 tons of material outside of warheads is itself extremely uncertain. Russia has never formally declared how much HEU or separated plutonium it has, how much of those stockpiles are in warheads, or how much material is in each of its many dif-

D.C.: National Academy Press, 2005; available at http://fermat.nap.edu/catalog/11377.html as of 4 April 2006).

[21] See discussion of this point in Matthew Bunn and Anthony Wier, *Securing the Bomb: An Agenda for Action* (Cambridge, Mass., and Washington, D.C.: Project on Managing the Atom, Harvard University, and Nuclear Threat Initiative, 2004; available at http://www.nti.org/e_research/cnwm/overview/2004report.asp as of 1 February 2006), p. 37.

[22] Interview with DOE officials, October 2005.

[23] Interview with DOE official, July 2004.

[24] Data provided by DOE, October 2005. This is confirmed in U.S. Department of Energy, *Performance and Accountability Report: FY 2005*, p. 95.

[25] Data provided by DOE, October 2005.

ferent facilities. Most of that information is still considered a state secret in Russia.

Comprehensive upgrades have been completed for all of the nuclear material in Russia's naval nuclear complex, all of the nuclear material in the non-Russian states of the former Soviet Union, and nearly all of the nuclear material at Russia's civilian sites. Nearly all of the material for which comprehensive upgrades have not yet been completed is located at a small number of massive sites in Russia's nuclear weapons complex, for which the access issue has taken the most time to resolve.

**Rate of progress.** During FY 2005, comprehensive upgrades were completed on an additional 3% of the weapons-usable nuclear material outside of nuclear weapons in the former Soviet Union (roughly 18 tons of additional material), increasing the fraction with comprehensive upgrades from 26% to 29%.[26] The year before, DOE completed security upgrades on some 4% of material.[27] Rapid upgrades were also completed on an additional 3% of the material, bringing the total with at least rapid upgrades completed from 46% to 49%.

DOE had hoped to complete comprehensive upgrades for 11% of the potentially vulnerable nuclear material in Russia during FY 2005, rather than 3%; the gap between performance and intention is attributable to the failure to gain access to the serial production enterprises.[28]

DOE hopes to complete comprehensive upgrades on the remaining 71% of the material in Russia by the end of 2008, assuming, as described above, that they rapidly reach agreement with Russia on approaches to carrying out upgrades at the serial production enterprises without compromising secrets. This will clearly require a dramatic acceleration of the past pace, as measured by the fraction of material upgraded each year. But because the program has completed upgrades at the buildings with small amounts of material, and is now implementing upgrades at buildings with huge quantities of material, such acceleration may well be in prospect. The joint action plan agreed with Russia specifies what upgrades will be installed where and when, to meet the agreed-upon target of completing all of the agreed work by the end of 2008. Even so, meeting that target will likely require sustained leadership from all levels of government to overcome obstacles to progress as they arise.

### *Securing Metric 3: Security Upgrades on Russian Sites Containing Warheads*

**Fraction accomplished.** The U.S. Department of Defense (DOD) and DOE are both working with Russian counterparts to install modern security systems at many Russian nuclear warhead storage sites. Measuring progress in aiding security at warhead storage sites is inevitably murkier, as neither the U.S. nor Russian government has published current, detailed estimates of how many nuclear warheads exist in Russia, at how many sites. Even the basic question of what fraction of Russia's warhead sites are covered by current U.S. plans for warhead security upgrades can only be partially answered from publicly available data.[29]

[26] The FY 2004 figure is at U.S. Department of Energy, *FY 2006 Defense Nuclear Nonproliferation Budget Request*, p. 485.

[27] Bunn and Wier, *Securing the Bomb 2005*, p. 31.

[28] U.S. Department of Energy, *FY 2006 Defense Nuclear Nonproliferation Budget Request*, p. 485.

[29] We are grateful to Charles L. Thornton of the University of Maryland, and to several U.S. govern-

It is also important to note that the number of sites to be secured is not necessarily fixed from year to year. Russia appears to be reducing the number of sites where its warheads are stored.[30] At a June 2005 press conference, General Igor Valynkin, head of the organization charged with the nuclear warhead management and security in Russia, the 12th Main Directorate of the Ministry of Defense (known by its Russian acronym as the 12th GUMO), stated, "Earlier, we had about 120 such [nuclear warhead] storage facilities, now we have reduced them more than two times and will reduce further as necessary."[31] It is not clear whether General Valynkin was referring to sites with permanent storage bunkers or including temporary facilities as well, or when the consolidation he described occurred; much of it may have been associated with the pull-back of Soviet weapons from Eastern Europe and the non-Russian republics. (Russia still appears to have the world's largest nuclear warhead storage and handling infrastructure, however, and major further reductions in the *number* of warhead sites are very important, in order to provide higher security at lower cost for the remaining sites.[32] Current U.S.-funded programs, however, have not focused on assistance in reducing the number of Russian warhead sites, though assistance with warhead transports has presumably helped in removing warheads from some sites Russia had decided to close down.)

After President Bush and President Putin agreed at their February 2005 summit in Bratislava, Slovakia, to develop a joint plan for security improvements, the Russian Ministry of Defense transmitted a list of some 42 sites for further cooperation on upgrades.[33] Of those 42 sites, 18 were reportedly new sites where cooperative upgrade work had not previously been agreed;[34] an interagency process assigned 8 of those new sites to DOD and 7 to DOE.[35] The U.S. government declined to cooperate at a few sites for various policy reasons, such as not wanting to improve Russian operational capability (a January 2003 interagency decision prohibited most upgrades for warhead handling areas at operational bases for that reason).[36]

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ment officials, for helping us better understand the limited publicly available information.

[30] For analyses calling for consolidating warheads in Russia to a much smaller number of sites, see Harold P. Smith, Jr., "Consolidating Threat Reduction," *Arms Control Today* (November 2003; available at http://www.armscontrol.org/act/2003_11/Smith.asp as of 22 March 2006); Gunnar Arbman and Charles Thornton, *Russia's Tactical Nuclear Weapons: Part II: Technical Issues and Policy Recommendations*, FOI-R—1588—SE (Stockholm: Swedish Defense Research Agency, 2005; available at http://www.foi.se/upload/pdf/FOI-RussiasTacticalNuclearWeapons.pdf as of 12 April 2006).

[31] Alexander Konovalov and Vladislav Kuznetsov, "Russia Reduces Nuclear Warheads by 75 Percent under START I," *ITAR-TASS*, 22 June 2005.

[32] For discussions, see, for example, Smith, "Consolidating Threat Reduction"; Gunnar Arbman and Charles Thornton, *Russia's Tactical Nuclear Weapons: Part I: Background and Policy Issues*, FOI-R—1057—SE (Stockholm: Swedish Defense Research Agency, 2003). Similarly, Colonel-General Yevgeny Maslin, retired commander of the 12th GUMO emphasized the need to reduce the number of sites as a key element of improving the sustainability of the upgrades now being installed. Personal communication, October 2005.

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

[34] Carla Anne Robbins and Cullison, "Closed Doors: In Russia, Securing Its Nuclear Arsenal Is an Uphill Battle."

[35] U.S. Department of Defense, *FY 2007 CTR Annual Report*, p. 28.

[36] U.S. Congress, Government Accountability Office, *Weapons of Mass Destruction: Additional Russian Cooperation Needed to Facilitate U.S. Efforts to Improve Security at Russian Sites*, GAO-03-482 (Washington, D.C.: GAO, 2003; available at http://www.gao.

With the post-Bratislava agreement for enhanced cooperation, DOE now plans to perform some level of upgrade on 39 Navy sites, 25 Strategic Rocket Forces (SRF) sites, and 9 sites managed by the 12th GUMO, for a total of 73 sites.[37] Of the 39 Navy sites, 6 are long-term storage sites.[38] DOD now states that it plans to provide upgrades for 24 warhead sites under the control of, or supporting, the 12th GUMO, the SRF, and the Russian Air Force.[39] Thus in total, U.S.-sponsored upgrade work is planned at 97 Russian warhead sites.[40]

gov/new.items/d03482.pdf as of 4 March 2006), pp. 33-34. In the past DOE has also declined to offer assistance for three naval sites, apparently because there should not be warheads there if Russia is fulfilling its pledges under the 1991–1992 Presidential Nuclear Initiatives. Russian requests for assistance at these three Navy sites provoked considerable concern and suspicion within the U.S. government. Interviews with DOE, DOD, and national laboratory officials, 2003 and February–March 2004. The U.S. government has apparently also declined to support upgrades at a site in the Russian enclave of Kaliningrad, a site near the Black Sea, and possibly others.

[37] U.S. Department of Energy, *FY 2007 Defense Nuclear Nonproliferation Budget Request*, p. 515. The previous year, DOE had projected carrying out upgrades on 39 Navy sites, 19 SRF sites, and 12 12th GUMO sites. Of the 39 Navy warhead sites, most are sites where DOE completed initial upgrades, but will not provide additional upgrades or site-level maintenance after the interagency decision that in most cases support would not be provided for upgrading warhead-handling sites.

[38] U.S. Department of Defense, *FY 2007 CTR Annual Report*, p. 28.

[39] U.S. Department of Defense, *Fiscal Year (FY) 2007 Budget Estimates: Former Soviet Union Threat Reduction* (Washington, D.C.: U.S. Department of Defense, 2006; available at http://www.dod.mil/comptroller/defbudget/fy2007/budget_justification/index.html as of 12 April 2006), p. 762.

[40] In the past, DOD and DOE published numbers of warhead sites appear not to have been carefully coordinated, and it appears that some sites were included on both lists in the past. In last year's report we did not realize this, and estimated that 112 total sites were targeted by the U.S. government, citing a DOD goal of completing upgrades at 42 sites, and

It is difficult to assess the total number of warhead sites in Russia, in order to assess what fraction of that total is covered by the 97 sites where cooperation has now been agreed. While DOD has made clear that the list now agreed includes all the sites where it plans to offer security upgrades,[41] it is clear that there are a small number of permanent warhead storage sites and a larger number of temporary warhead locations (such as warhead handling areas at bases or rail transfer points) where the two sides have not agreed to cooperate on security upgrades. Upgrades at a few of the sites not yet covered by U.S. programs, however, may be being sponsored by other Global Partnership donor countries. In some cases, sites are not on the agreed list because the U.S. government has policy concerns about cooperation at those sites; in others, it is because Russia has not included them on the lists available for cooperation. The number of temporary sites that exist in Russia is substantial. Indeed, prior to the January 2003 decision, DOD had considered providing a package of security upgrades for dozens of temporary warhead facilities, of which only a fraction are covered by the current agreed list of sites for upgrades.[42] There is also the entire category of front-line tactical warhead sites, which are not covered in current plans. If Russia has fully implemented the 1991-1992 U.S.-Russian nuclear initiatives, these in general should no longer

a DOE goal of upgrades at 70 sites; Bunn and Wier, *Securing the Bomb 2005*, pp. 34-35. This year, DOD uses the same number to describe the sites where DOE is working that DOE does, suggesting that the numbers are now coordinated and overlap has been eliminated, making it possible to add the two departments' numbers to arrive at a total.

[41] DOD says that "the current list for site security upgrades represents the plan for completing all U.S.-Russia cooperative work in this assistance area." U.S. Department of Defense, *FY 2007 CTR Annual Report*, p. 28.

[42] Personal communication, May 2005.

have warheads in them, but a number of them continue to exist, some of the units continue to train for nuclear missions, and U.S. officials have occasionally asserted that Russia has not fully implemented its side of these initiatives.[43] It thus appears that the total number of warhead sites, including both permanent and temporary sites but not counting the front-line tactical sites that may no longer have warheads, is likely to be in the range of 110-130, leaving roughly 10-30 sites not yet subject to cooperation.[44]

By the end of FY 2005, DOE had completed security upgrades for 37 Russian Navy sites and 10 SRF sites, while DOD had completed security upgrades at 1 storage site (it is not clear whether the storage site is controlled directly by the 12th GUMO or one of the services).[45] These 48 sites represent just under 50% of the 97 sites targeted by DOD and DOE, and roughly 40% of our estimate of the total number of sites.[46]

By the end of FY 2004, DOE had already completed at least rapid upgrades on all 39 of the Navy sites where DOE is working.[47] As of February 2005, DOE was hoping to have completed at least rapid upgrades on 17 SRF sites by the end of FY 2005, but DOE has not released subsequent data to confirm whether this target was met.[48] Upgrades at 12th GUMO sites where DOE is working are expected to

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[43] Wade Boese, "U.S., Russia Debate Tactical Nuclear Arms," *Arms Control Today* (November 2004; available at http://www.armscontrol.org/act/2004_11/Tactical_Nukes.asp as of 22 March 2006). We are grateful to Charles L. Thornton for making this point to us.

[44] In previous years' reports, we compared official U.S. government estimates of the sites targeted for upgrades to an unclassified estimate of warhead storage and handling areas, counting each individually secured perimeter. Bunn and Wier, *Securing the Bomb 2005*, pp. 34-37; Bunn and Wier, *Securing the Bomb: An Agenda for Action*, pp. 51-56. We used an estimate that warheads were stored at some 150-210 individually secured locations, whether they were fixed bunkers or locations where warheads are temporarily stored. This total assumed 50-70 national stockpile sites, 60-80 deployed, service-level storage sites, and 40-60 temporary sites (such as rail transfer points and warhead handling areas at operational bases). The numbers were from Charles Thornton, presentation, Harvard University, October 24, 2003. We were mistaken in assuming that each "site" designated by DOD or DOE corresponded to one such separately fenced area. Rather, the DOD or DOE "sites" come from designations provided by the Russian Ministry of Defense, some of which include several storage bunkers at a single "site." Both types of estimates are correct on their own terms, but the numbers they generate cannot be compared to each other; any error in applying these numbers from different publicly available sources was entirely our own. The shift this year to numbers based on DOD and DOE approach is the reason why our estimates of the total fraction of the warhead work accomplished have substantially increased.

Most of the estimated 20-30 uncovered sites are temporary sites. Some temporary warhead sites might not require permanent, fixed security equipment equivalent to the equipment provided in rapid upgrades, much less more elaborate comprehensive upgrades; other, rapidly deployable but temporary security measures may be appropriate for such sites, though there is currently no publicly available information suggesting that such temporary security measures have been provided for these types of temporary sites.

[45] For DOE numbers, see U.S. Department of Energy, *FY 2007 Defense Nuclear Nonproliferation Budget Request*, pp. 514-515. For DOD numbers, see U.S. Department of Defense, *FY 2007 CTR Annual Report*, p. 28. The U.S. government has concluded that at 23 of the 39 targeted Navy sites further support is not permitted, and upgrades are completed, so DOE counts these sites under its total of 37 completed Navy warhead sites even though they will not receive comprehensive upgrades. Personal communication from DOE program official, February 2004.

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

[47] Calculations based on unpublished data provided by DOE, February 2005.

[48] Calculations based on unpublished data provided by DOE, February 2005.

commence in FY 2006.[49] In the DOD program, site designs have been completed, and equipment has been ordered, for 11 sites, and contracts are in place to work on 16 sites.[50]

**Rate of progress.** During FY 2005, DOE completed upgrades on 3 additional Navy sites and 8 SRF sites, meeting its target of 11 sites.[51] DOD completed upgrades at 1 site, and completed designs for 2 additional sites.[52] Using the baselines discussed above, our estimate of the work completed in FY 2005 is approximately 10%, rising from approximately 30% to approximately 40%.[53]

In last year's report, we argued that a substantial acceleration would be needed to complete upgrades at warhead storage sites by the end of 2008, as seemed to be envisioned in the Bratislava summit statement. With the U.S.-Russian agreement following the Bratislava summit, it appears such acceleration is now the official plan: the United States has now committed to complete all planned upgrades in Russia by calendar year 2008.[54]

For FY 2006 DOE expects to complete the final 2 Navy sites and 2 more SRF sites; it wants to complete 5 more sites in FY 2007, 6 in FY 2008, and 9 presumably in the first three months of FY 2009, before calendar year 2008 comes to an end.[55]

DOD did not explicitly state how much it plans to accomplish in FY 2006, but in February 2006 DOD requested $44.5 in FY 2006 supplemental funding to accelerate the pace of upgrades, suggesting a rapid planned pace during FY 2006. By the end of calendar year 2007, DOD expects to have completed the 16 sites for which contracts are already in place; DOD wants to complete upgrades for the 8 additional sites by the end of 2008.[56]

[49] U.S. Department of Energy, *FY 2007 Defense Nuclear Nonproliferation Budget Request*, p. 515.

[50] U.S. Department of Defense, *FY 2007 CTR Annual Report*, p. 28. In the past, DOD also provided 123 sets of "quick fix" sets of security equipment—similar in some respects to what DOE calls "rapid upgrades"—to Russia's Ministry of Defense (MOD), but because of earlier disagreements about site access, the MOD was slow to use its own funds to install the equipment; see "Warhead Security: The Saga of the Slow 'Quick Fix'," in Bunn and Wier, *Securing the Bomb: An Agenda for Action*, pp. 53-54. As of late 2003, MOD had officially certified that 47 quick fix sets were installed, but had informally indicated that roughly half of them had been installed. After discussions of U.S. support for installations of these sets began, MOD largely stopped providing its own funds to install them. (Personal communication with DTRA official, February 2004.) Any additional sets that have been installed since then have been installed by the teams funded by the DOE and DOD programs. Given that there appears to be much less gap between the total number of sites and the number of sites where the United States is planning to offer assistance, it appears likely that much of this installed equipment will serve as initial upgrades upon which some U.S.-provided upgrades will improve. See the discussion in U.S. Department of Defense, *Cooperative Threat Reduction Annual Report to Congress: Fiscal Year 2006* (Washington, D.C.: U.S. Department of Defense, 2005), p. 41.

[51] Calculations from comparing the following: U.S. Department of Energy, *Performance and Accountability Report: FY 2005*, and U.S. Department of Energy, *Performance and Accountability Report: FY 2004*.

[52] Calculations from comparing the following: U.S. Department of Defense, *Cooperative Threat Reduction Annual Report to Congress: Fiscal Year 2006*, p. 41, and U.S. Department of Defense, *FY 2007 CTR Annual Report*, p. 28.

[53] Again, this figure rounds to the nearest 5%.

[54] U.S. Department of Defense, *FY 2007 CTR Annual Report*, p. 28. Similarly, DOE has specified December 2008 as the target for completing upgrades at all the sites where it is working. See U.S. Department of Energy, *FY 2007 Defense Nuclear Nonproliferation Budget Request*, p. 514.

[55] U.S. Department of Energy, *FY 2007 Defense Nuclear Nonproliferation Budget Request*, p. 515.

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

### *Securing Metric 4: HEU Reactor Sites Outside the Former USSR and the United States With HEU Removed or Security Upgrades Completed*

Neither the United States government nor any other government or organization has a comprehensive picture of nuclear security around the world, or what work would have to be done, at which sites, to improve nuclear security enough to reduce the risk of nuclear theft and terrorism to a minimal level. Since the size of the job is not yet well defined, it is difficult to assess what fraction of the job is done.

It is possible, however, to lay out the different pieces of the global job that needs to be done, and discuss in general terms which of them are covered by current U.S. programs, and how much those programs have accomplished. To ensure that every cache of nuclear weapons or weapons-usable nuclear materials worldwide is effectively and sustainably secured and accounted for, it would be important to put in place strengthened security measures in each of the types of countries where these stockpiles exist and to remove the weapons or materials entirely from as many sites as possible (addressing those sites whose nuclear holdings cannot be effectively defended where they are, and achieving higher security at lower cost at the remaining sites).

This would include improved nuclear security in states with nuclear weapons, in high-income non-nuclear-weapon states, and in lower income non-nuclear-weapon states, along with forging global standards for nuclear security that would help ensure that *all* nuclear weapons and weapons-usable materials were effectively secured. Efforts to reduce the number of locations with dangerous nuclear stockpiles would include consolidating nuclear weapons, military stockpiles of nuclear material, civilian HEU, and civilian separated plutonium. Consolidating civilian HEU would include: converting research reactors and other civilian reactors to use low-enriched uranium (LEU) instead of HEU; shutting down research reactors that were no longer needed; removing the stocks of HEU (both fresh and irradiated) formerly used at these facilities; removing HEU from as many of the non-research-reactor civilian sites where it exists (such as fuel processing facilities) as possible; and avoiding the use of HEU in new research or power reactors. Below, we briefly review the current status in each of these categories.

**Improved security in states with nuclear weapons: modest progress outside the United States and Russia.** In addition to 100% of the world's nuclear weapons, states with nuclear weapons own more than 95% of the world's HEU and separated plutonium; their share of the buildings where such materials exist is only modestly lower. Hence, the state of nuclear security in the states with nuclear weapons, and of progress in improving it, is a particularly important first area to examine in elucidating the global picture of nuclear security.

The U.S. government has chosen to upgrade nuclear security in the United States substantially since the 9/11 attacks. Although the terrorist threat within the United States appears to be substantially lower than in many other countries—as reflected by the complete absence of further terrorist attacks on U.S. soil since the 9/11 attacks—DOE facilities with weapons-usable nuclear material are reportedly now required to be able to defend against a squad-sized force of well-trained attackers with sophisticated armaments and equipment, along with multiple insiders.[57] The Nuclear Regulatory Commission (NRC) has also increased security requirements for the large HEU fuel facilities it regulates. U.S. HEU-fueled research reactors regulated by the NRC, however, continue to have minimal security measures in place.[58]

Similarly, as just discussed, U.S.-funded programs, programs funded by other donor states, and Russia's own efforts have, between them, significantly improved nuclear security in Russia in recent years—though the measures being put in place are not likely to provide effective defenses against the scale of threats that DOE is requiring its facilities to defend against.

France and the United Kingdom have each reportedly strengthened nuclear security measures since the 9/11 attacks, but nuclear security in these countries has not been the focus of either U.S.-funded programs or U.S. diplomacy. Publicly available information is sparse, but suggests that security measures for some categories of weapons-usable material are significantly less than those that would apply in the United States.[59]

As noted in Chapter 2, DOE has been working to build cooperation with China on improving security for nuclear stockpiles there, but as of the end of FY 2005, upgrades had been completed for only one civilian facility with weapons-usable nuclear material, and there was as yet no agreement on implementing a broader program of upgrades. In India, no cooperation to upgrade nuclear security is yet underway, and hence no upgrades have been completed. Public reports suggest that nuclear security cooperation with Pakistan may be under way,[60] but no official information has been publicly

[57] Project on Government Oversight, "Energy Ups Their DBT, NRC Still Making Excuses." For a discussion of security improvements at DOE since the 9/11 attacks, see, for example, Committee on Energy and Commerce, Subcommittee on Oversight and Investigations, *A Review of Security Initiatives at DOE Nuclear Facilities*, U.S. House of Representatives, 109th Congress, 1st Session (18 March 2005; available at http://energycommerce.house.gov/108/Hearings/03182005hearing1457/hearing.htm as of 15 April 2006). While little information is publicly available about the measures DOD is taking to protect nuclear warheads and HEU fuel in its custody, they are thought to be generally comparable to DOE's measures. Requirements for the two major privately owned HEU processing facilities regulated by the U.S. Nuclear Regulatory Commission (NRC) have also increased since 9/11, but are reportedly less than the requirements at DOE facilities. See Project on Government Oversight, *U.S. Nuclear Weapons Complex: Homeland Security Opportunities* (Washington, D.C.: POGO, 2005; available at http://pogo.org/p/homeland/ho-050301-consolidation.html as of 4 April 2006). For a discussion of the new measures NRC has required (focusing more on power plant security against sabotage than on nuclear material security against theft, which has received less public attention in the case of NRC facilities), see, for example Committee on Government Reform, Subcommittee on National Security, Emerging Threats, and International Relations, *Nuclear Security: Has the NRC Strengthened Facility Standards since 9/11?* U.S. House of Representatives, 109th Congress, 2nd Session (4 April 2006; available at http://reform.house.gov/NSETIR/Hearings/EventSingle.aspx?EventID=41937 as of 6 May 2006). Unfortunately, HEU-fueled research reactors regulated by the NRC still have very modest security measures in place—often not even including a fence around the building or a night watchman on duty. See "Radioactive Road Trip" in *PrimeTime Live* (ABC News, 2005).

[58] See, for example, "Radioactive Road Trip." HEU located at research reactors is exempted from most NRC requirements for Category I nuclear material. See U.S. Nuclear Regulatory Commission, "Part 73-Physical Protection of Plants and Materials," in Title 10, *Code of Federal Regulations* (Washington, D.C.: U.S. Government Printing Office; available at http://www.nrc.gov/reading-rm/doc-collections/cfr/part073/full-text.html as of 28 March 2006).

[59] See, for example, Timm, *Security Assessment Report for Plutonium Transport in France*.

[60] Kenneth N. Luongo and Isabelle Williams, "Seizing the Moment: Using the U.S.-Indian Nuclear Deal to Improve Fissile Material Security," *Arms Control Today* (May 2006; available at http://www.armscontrol.org/act/2006_05/usindiafissilesecurity.asp as of 12 May 2006).

released. No nuclear security cooperation is currently planned with Israel (whose stockpiles are believed to be highly secure, given Israel's long experience with protecting against terrorist threats) or with North Korea. In short, outside of Russia and the United States, there appears to be both slow progress and important gaps in U.S. programs to work with states with nuclear weapons to ensure that effective nuclear security measures are put in place.

**Improved security in high-income non-nuclear-weapon states: not covered by U.S. programs.** Most of the weapons-usable nuclear material outside of the states with nuclear weapons is in developed, high-income countries such as Germany and Japan. Nuclear security in high-income countries has not been the focus of U.S.-funded programs. DOE has indicated that it assumes that security in high-income countries is already sufficient.[61] As discussed in the previous chapter, however, this assumption is not correct in some cases, particularly when it comes to civilian research reactors fueled with HEU, most of which have only minimal security measures in place (including in the United States itself), even in the aftermath of post–9/11 steps to tighten nuclear security rules that several of these countries have taken. The security measures at HEU-fueled research reactors in many of these countries (as with the United States) would have little chance of defending against a determined and well-armed terrorist attack even of relatively limited size—and might not be sufficient to prevent determined insiders from removing HEU.

In general, these countries do have physical protection measures in place that comply with IAEA recommendations, and in the case of countries that received their nuclear material from the United States, there are occasional reviews required by U.S. law to confirm that this is the case. But as noted earlier, the IAEA recommendations are quite vague. Complying with them does not in itself ensure that facilities are effectively protected against the outsider and insider threats that exist where they are located—and the U.S. visits assess only whether the facilities are following the recommendations, not whether their security measures seem likely to be effective in defeating credible threats. While there have been some efforts to work with these countries to ensure that they put in place effective nuclear security measures, much more remains to be done. Of course, in wealthy countries such measures would not necessarily have to be paid for by the United States (though to the extent improvements are pursued in partnership-based cooperation, with ideas and expertise flowing in both directions, the United States should pay for its share of that work).

**Improved security in lower-income non-nuclear-weapon states: limited progress outside the former Soviet Union.** Because of the assumption that nuclear security in high-income countries is already sufficient, DOE has focused its nuclear security upgrade work in countries with lower incomes—developing countries, countries in transition from communist rule, and a few of the less wealthy developed countries (such as Greece and Portugal). Most of the upgrades that have been done, however, have been in the former Soviet Union, and therefore are already included in the metrics discussed above. To date, the U.S. Research Reactor Security effort (a sub-program of GTRI) and its predecessors have completed U.S.-funded security upgrades for only seven facilities in non-nuclear-weapon states outside the former Soviet Union: one each in the Czech Republic,

[61] Data provided by DOE to Rep. Robert Andrews (D-NJ), April 2006.

Greece, Hungary, Poland, and Portugal, and two in Romania).[62] All of these upgrades were intended only to meet the IAEA recommendations, not to provide defense against a substantial design basis threat. Hence, security at these sites after the upgrades were completed is probably comparable to security at many other HEU-fueled research reactors in developed and developing countries—and, like those other facilities, is not sufficient to protect against the threats that terrorists and criminals have shown they can pose.

DOE has presented a very different approach to assessing how much of the job of securing civilian nuclear materials is done. First, their measure focuses only on HEU-fueled research reactors, rather than on weapons-usable nuclear materials more generally. Second, DOE counts all of the research-reactor-related HEU facilities in the former Soviet Union that have received security upgrades in its measure of the work completed; since those sites are already covered in the metrics above, we do not count them here. Third, DOE excludes all HEU-fueled research reactors in high-income countries from the total to be addressed, assuming that all of those facilities have adequate security already (which is not an accurate assumption, as discussed above). With those assumptions, they conclude that there are 103 sites to be addressed (the HEU-fueled research reactor sites outside of high-income countries), of which the United States has already provided security upgrades for 76, some 74% of the total.[63] All but seven of these 76, however, appear to be former Soviet sites. The sites addressed outside the former Soviet Union are a very, very small fraction of the total.

[62] Data provided by DOE, December 2005.

[63] Data provided to Rep. Robert Andrews (D-NJ), April 2006.

**Creating effective global nuclear security standards: very limited progress.** The U.S. government has not been actively pressing to create effective global nuclear security standards, and hence there has been little progress in this direction. As noted in Chapter 2, the recently approved amendment to the physical protection convention and the nuclear terrorism convention both include useful provisions, but neither establishes any clear global standard for security. UNSCR 1540 legally requires all states to provide "appropriate effective" security and accounting for whatever nuclear stockpiles they may have, but no one as yet has defined what the essential elements of an "appropriate effective" system are. The purely voluntary IAEA recommendations are the closest thing to a global nuclear security standard that now exists, and a fifth revision of these recommendations is now being considered. It is highly unlikely, however, that this revision will result in standards that would ensure that all facilities that complied were effectively protected against demonstrated terrorist and criminal threats.

**Consolidating nuclear weapons: not covered by U.S. programs.** As noted above, current U.S.-funded programs have generally not focused on assistance in reducing the number of Russian warhead sites, though U.S.-funded assistance for secure warhead transports has presumably helped Russia to remove warheads from some sites.

The number of sites where U.S. nuclear weapons exist has also been reduced substantially in recent years. Nuclear weapons have been removed entirely from the U.S. Army, from naval surface vessels, and from all but a few overseas locations, largely as part of the Presidential Nuclear Initiatives of 1991-1992. It appears that the United Kingdom and

France have also reduced the number of sites where nuclear weapons exist with the consolidation of the British nuclear deterrent in its submarine fleet and the consolidation of the French nuclear forces in the submarine fleet and a limited number of bombers. No U.S. initiatives have focused on warhead consolidation in these countries, however. Similarly, there have been no U.S. initiatives focused on warhead consolidation in China, India, Pakistan, or Israel. Proposals now being discussed in the six-party talks would eliminate all nuclear weapons in North Korea—the ultimate in consolidation—but it remains to be seen whether those discussions will succeed.

**Consolidating military stocks of nuclear material: limited progress, major gaps.** Most of the world's weapons-usable nuclear material is in stockpiles designated for defense purposes; the defense sector accounts for most of the global total of buildings where such material exists as well. With the end of the Cold War, much of this material and many of these buildings are no longer realistically needed. Both the U.S. Nuclear Cities Initiative and the materials protection, control, and accounting (MPC&A) program have been working with Russia to consolidate these materials into a smaller number of buildings and sites. Successes include the substantial reduction in the number of Russian Navy sites with HEU, the closure of the two smallest of the four Russian nuclear weapons assembly/disassembly facilities (though only one of these involved U.S. assistance), and Russia's decision (without U.S. help or prodding) to close one of its two facilities for producing plutonium and HEU weapons components. But overall, progress has been limited: there are still thought to be more than 200 buildings in Russia with weapons-usable nuclear material, most of which are at naval or nuclear-weapons-complex sites. Similarly, the United States has made some progress in consolidating the nuclear material in DOE's defense complex, with steps such as the closure of the Rocky Flats plutonium facility, the removal of weapons-usable nuclear material from Technical Area 18 (TA-18) at Los Alamos, and a substantial reduction of the number of buildings with nuclear material at Hanford. But there is still a long way to go.[64] DOE is now planning to eliminate major caches of nuclear material from both the Sandia and Livermore national laboratories, in part to reduce safeguards and security costs, but it may be years before this is accomplished.[65] There do not appear to be any U.S. government initiatives focused on working with other states with weapons-usable nuclear materials for defense purposes to consolidate them into fewer locations. Indeed, GTRI has largely defined its scope as focusing only on civilian nuclear materials, largely excluding even those research reactors used for defense purposes.

**Converting HEU-fueled reactors: some progress, many not covered by U.S. programs.** Both separated plutonium and HEU have civil uses, making it important to consolidate civil stockpiles as well. Consolidation of civil plutonium is discussed below. The most common civil use of HEU around the world is in research reactors, and these are some of the locations where HEU is potentially most vulnerable to theft. Hence, removing the HEU from as many of these sites as possible is a key part of the consolidation agenda.

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[64] Project on Government Oversight, *U.S. Nuclear Weapons Complex: Homeland Security Opportunities*.

[65] See, for example, discussion in Committee on Armed Services, Strategic Forces Subcommittee, *Plans for Transforming the Department of Energy's Nuclear Weapons Complex*, U.S. House of Representatives, 109th Congress, 2nd Session (5 April 2006).

As noted in the last chapter, approximately 135 research reactors in nearly 40 countries worldwide still use HEU fuels (representing roughly half of the over 270 research reactors worldwide),[66] and a surprising number of these (and of their associated fuel facilities) have enough material on-site for a nuclear bomb. The reactors still operating with HEU use an estimated 1,000 kilograms of HEU each year, of various enrichments.[67]

As part of GTRI, DOE is seeking, where possible, to convert HEU-fueled research reactors to use LEU fuel, which cannot be used in nuclear weapons without complex re-enrichment. GTRI hopes to complete conversion of 106 HEU-fueled reactors by 2014.[68] Of these, 32 had been fully converted to LEU by the end of FY 2005, with eight more partly converted (and therefore still using some HEU fuel in their cores).[69] The 40 converted or partially converted to date (stretching back to the origins of the conversion program in 1978) represent some 38% of the target group. The 32 fully converted reactors represent 30% of the targeted group.

With 32 of the 106 reactors already fully converted, there were 74 reactors in the targeted group that still use HEU fuel as of the end of FY 2005, and hence these 74 are on the global list of approximately 135 HEU-fueled reactors. That leaves some 61 reactors, roughly 45% of the world's current HEU-fueled research reactors, that are *not* covered by DOE's conversion effort (although GTRI is examining what would be required to expand the list to cover a portion of these additional reactors).[70]

There are a variety of reasons why particular reactors are not included on the list slated for conversion. Virtually no critical assemblies—research facilities designed to be just barely critical, generating almost no power, used to measure key nuclear cross-sections or to simulate the cores of new power reactor designs—are targeted for conversion. In many cases these assemblies would be difficult to convert, though a recent IAEA consultation recommended that opportunities for reducing enrichment at critical assemblies

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[66] Data compiled by Frank von Hippel and Alexander Glasser, Princeton University, personal communication, December 2005. DOE officials report, however, that additional HEU reactors continue to be identified in discussions with foreign experts, especially in Russia (interview with DOE officials, December 2005).

[67] Alexander Glaser and Frank N. von Hippel, "Global Cleanout: Reducing the Threat of HEU-Fueled Nuclear Terrorism," *Arms Control Today* (January/February 2006; available at http://www.armscontrol.org/act/2006_01-02/JANFEB-heuFeature.asp as of 8 June 2006).

[68] DOE modified its list of reactors targeted for conversion in the past year, removing some reactors that had been mistakenly included even though no fuel suitable for converting them was in development, and adding some reactors that now appear possible to convert. For the latest list, see Christopher Landers, "Reactors Identified for Conversion: Reduced Enrichment for Research and Test Reactors (RERTR) Program," in *RERTR 2005: 27th International Meeting on Reduced Enrichment for Research and Test Reactors, Boston, Mass., 6-10 November 2005* (Argonne, Ill.: Argonne National Laboratory, 2005; available at http://www.rertr.anl.gov/RERTR27/PDF/S9-1_Landers.pdf as of 20 June 2006).

[69] For 40 reactors converted, see U.S. Department of Energy, *FY 2007 Defense Nuclear Nonproliferation Budget Request*, p. 562. For a more detailed account, listing all the reactors targeted for conversion and their status (including the statement that only 32 reactors were fully converted), see Landers, "Reactors Identified for Conversion." There is a modest discrepancy in these sources, both from GTRI, in that Landers refers to 42 reactors fully or partially converted at that time; we rely here on the budget justifications as the more authoritative figure.

[70] Data compiled by Frank von Hippel and Alexander Glasser, Princeton University, personal communication, December 2005. Consideration of adding additional reactors is from interview with DOE officials, December 2005.

around the world be examined, and it appears that some of those that now use 90% enriched material could get by with 30% enriched material posing much less risk.[71] Critical assemblies are a very important gap in the conversion effort, as some critical assemblies have hundreds of kilograms or even tons of HEU or plutonium; at critical assemblies, this material is hardly radioactive at all, and would be quite easy to steal. (Indeed, at some assemblies, the researchers handle the fuel by hand.)

Similarly, most pulse reactors—reactors that generate short but intense bursts of power—are not covered by current conversion efforts (in part because the conversion efforts are focused on civilian reactors, and most pulse reactors are used for defense research), and some of these reactors also have very large quantities of high-grade nuclear material.

Reactors with unique specialty fuels, fast-neutron reactors, and research reactors that operate at high temperatures are also generally not covered by current conversion efforts because they could not use the LEU fuels developed to date or the denser fuels still in development.

Moreover, current conversion efforts have made little progress in Russia, which has the world's largest number of HEU-fueled reactors. Although some Russian reactors are on DOE's list of 106 reactors targeted for conversion, no Russian research reactors have yet converted to LEU, and Russia has resisted moving forward on conversion in formal government-to-government channels, insisting in the Bratislava summit statement that the endorsement of conversion apply only to "third countries." In an informal private initiative, however, a non-governmental organization in Russia has proposed to undertake a detailed study of conversion and shut-down possibilities for Russia's research reactors (as well as other issues related to nuclear materials at these sites) in cooperation with the Nuclear Threat Initiative. Similarly, in private conversations with non-government U.S. experts, representatives from a number of Russian sites have expressed interest in studying conversion of some major facilities to LEU, or shut-down of some unneeded critical assemblies.

In addition to using HEU as fuel, some research reactors use HEU as targets to be irradiated in order to produce medical isotopes. Roughly 85 kilograms of HEU per year are used for this purpose.[72] GTRI is also hoping to convert this production to the use of LEU, and has developed promising processes for doing so which have been adopted by smaller isotope suppliers (for example in Argentina and Australia). To date, however, the largest suppliers of medical isotopes have resisted conversion. Indeed, in 2005 these suppliers succeeded in convincing Congress to modify U.S. laws to ease restrictions on export of HEU to medical isotope suppliers not participating in efforts to convert to LEU.[73]

[71] Frank N. von Hippel, "Future Needs for Critical Assemblies," in *RERTR 2005: 27th International Meeting on Reduced Enrichment for Research and Test Reactors, Boston, Mass., 6-10 November 2005* (Argonne, Ill.: Argonne National Laboratory, 2005; available at http://www.rertr.anl.gov/RERTR27/PDF/S9-3_vonHippel.pdf as of 20 June 2006).

[72] U.S. Congress, Government Accountability Office, *Nuclear Nonproliferation: DOE Needs to Take Action to Further Reduce the Use of Weapons-Usable Uranium in Civilian Research Reactors*, GAO-04-807 (Washington, D.C.: GAO, 2004; available at http://www.gao.gov/new.items/d04807.pdf as of 2 February 2006), p. 2.

[73] For a critical account, see Alan J. Kuperman, "Bomb-Grade Bazaar," *Bulletin of the Atomic Scientists* (March/April 2006; available at http://www.thebulletin.org/article.php?art_ofn=ma06kuperman as of 20 June 2006).

In addition to research reactors, there are also icebreaker reactors, tritium and plutonium production reactors, and naval reactors that use substantial quantities of HEU fuel each year. HEU has also been used for space nuclear reactors in the past, and the United States recently set aside a portion of its excess HEU stockpile for possible future use in space reactors.[74] The U.S. government has not yet targeted these reactor types for conversion.[75] Russian experts have proposed a project to develop LEU fuels for the icebreaker fleet, however, and the Nuclear Threat Initiative is negotiating with them to provide initial funding for that effort.

The GTRI program estimates that, beyond the 40 research reactors already fully or partially converted, 43 more could convert to LEU fuels that have already been developed.[76] They have not done so because they have had only modest incentives to convert to LEU, which many reactor operators believe (generally incorrectly) will lead to lower reactor performance. While U.S. law limits export of new HEU fuel to reactors that could convert to LEU and have not done so, and the U.S. take-back offer is limited to fuel from reactors that have converted or agreed to do so, many of the reactors that have not yet converted already have HEU fuel for their lifetime, or at least for many years to come. DOE has not spelled out what additional incentives will be offered to convince reactor operators to convert to LEU; to date, DOE has offered assistance in some cases to help ensure that conversion would not be a major cost to the reactor operator, but has declined to offer incentives that would make reactors better off than they would be if they did not bother to convert.[77]

Another 23 of the reactors on the target list for conversion require new, higher-density fuels to be developed before they can convert to LEU without major losses in performance. High-density fuels based on uranium-molybdenum alloys (both solid and as dispersed powders) are in development; assuming that the solid alloy is as successful as it has been in early tests, and that cost-effective manufacturing processes for this fuel can be developed, this class of fuels could be used to convert all of these 23 reactors.

The 2014 date for completing the conversion of the targeted list of reactors has been criticized as being too far in the future. It is based on current expectations that high-density fuels will be qualified and become available in 2010, after which several years will be needed to convert all the reactors that will use those fuels. Unfortunately, accelerating that date would probably be difficult, and there is a substantial risk that the date will continue to slip.

As a metric of progress, DOE tracks the number of reactors converted. This metric provides a useful indicator of the progress of the particular policy tool of conversion. But undue reliance on this metric tends to divert attention from the reactors not covered on the targeted list, from encouraging reactors to shut down rather than convert (discussed below), from reactors that have already shut down or converted

[74] U.S. Department of Energy, *DOE to Remove 200 Metric Tons of Highly Enriched Uranium from U.S. Nuclear Weapons Stockpile* (Washington, D.C.: DOE, 2005; available at http://www.energy.gov/news/2617.htm as of 25 May 2006).

[75] For useful discussions, see Frank von Hippel, "A Comprehensive Approach to Elimination of Highly-Enriched Uranium from All Nuclear Reactor-Reactor Fuel Cycles," *Science and Global Security* 12, no. 3 (November 2004); Glaser and von Hippel, "Global Cleanout."

[76] Landers, "Reactors Identified for Conversion."

[77] Interview with DOE officials, December 2005.

but may still have HEU on-site, and from HEU stored at non-reactor facilities.

**Shutting down unneeded HEU-fueled research reactors: not covered by U.S. programs.** Many of the world's research reactors are aging and no longer offer research and testing benefits commensurate with their costs and risks. The IAEA has estimated that out of more than 270 operating research reactors in the world today, perhaps 30-40 are needed for the long term,[78] suggesting that 80-90% of the world's research reactor fleet should be shuttered. In many cases, it makes far more sense to shut down HEU-fueled reactors than to pay to convert them to LEU. Indeed, more HEU-fueled reactors have shut down since the RERTR program began in 1978 than have converted to LEU.

In particular, a recent IAEA consultation recommended a detailed examination of which of the world's critical assemblies (which, again, have particularly dangerous nuclear material and are generally not covered by current conversion efforts) are no longer needed, given the data that have already been collected and the ever-increasing possibilities of computer simulation.[79] The United States recently shut down the critical assemblies at TA-18 at Los Alamos, which, like many of the critical assemblies around the world, was a site that was very difficult to defend, and shipped the nuclear material to the secure Device Assembly Facility at the Nevada Test Site (where additional critical experiments will be done). Similarly, the United States is planning to shut down the pulse reactor at Sandia National Laboratories, and remove the weapon-grade material from that site.[80]

Unfortunately, however, neither the U.S. government nor any other government or international organization has any program in place to encourage governments to phase out support for unneeded research reactors, or to provide incentives to research reactor operators to shut down. This represents an important gap in current efforts to minimize and ultimately eliminate the civilian use of HEU.

**Removing stocks of HEU at research reactors: some progress, substantial stocks not yet covered by U.S. programs.** Of course, simply converting or shutting down research reactors is not enough. The HEU at these sites must be physically removed if the number of sites with HEU is to be reduced. The United States and the Soviet Union supplied more than 90% of the HEU for research reactors around the world, and as part of GTRI, DOE has programs in place to take U.S.-supplied HEU back to the United States, and to ship Soviet-supplied HEU back to Russia or blend it to LEU in the countries where it now exists.

In the case of Soviet-supplied HEU, it appears that as of the early 1990s when threat reduction efforts began, there were approximately 22-24 Soviet-supplied sites with HEU outside of Russia.[81] Since

[78] Iain Ritchie, "IAEA Presentation on Threat Reduction Activities," paper presented at The Global Threat Reduction Initiative International Partners' Conference, Vienna, Austria, 18-19 September 2004.

[79] Von Hippel, "Future Needs for Critical Assemblies."

[80] See, for example, discussion in *Transforming DOE's Nuclear Weapons Complex*.

[81] These include four sites at that time in Kazakhstan, three in Ukraine, two each in Uzbekistan and the Czech Republic, and one each in Belarus, Bulgaria, Georgia, Germany, Hungary, Latvia, Libya, North Korea, Poland, Romania, Vietnam, and Yugoslavia. (We are not counting, here, the Sukhumi I. Vekhua Institute of Physics and Technology in Sukhumi, Abkhazia, from which HEU was apparently stolen some time after the Georgian civil war broke out in the 1990s. Since HEU

***Table 3-1***
***U.S.-Assisted Removals of Russian-Origin Highly Enriched Uranium (HEU) Fuel***

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

then, by just after the end of FY 2005, U.S.-funded efforts had removed *all* the HEU from three of these facilities (the Ulba facility in Kazakhstan, from which nearly 600 kilograms of HEU was airlifted in 1994; a facility in Tbilisi, Georgia, whose HEU was airlifted to the United Kingdom in 1998; and the "Sparrow" research reactor in the Czech Republic, whose HEU was removed in October 2005). All the fresh, unirradiated HEU has been removed from seven more sites (Vinca, in Serbia, in 2002; Romania and Bulgaria in 2003; Libya, another site in the Czech Republic, and Uzbekistan in 2004; and Latvia in 2005),[82] but in these cases significant quantities of irradiated HEU, also posing a proliferation hazard, still remained. Table 3-1 lists the removals of Soviet-supplied HEU from various countries since threat reduction efforts began. In addition, the private Nuclear Threat Initiative partnered with Kazatomprom, the Kazakhstan nuclear company, to remove all the HEU from a fourth location, at Aqtau in Kazakhstan, and have it blended to LEU at the Ulba facility there (though some three tons of weapon-grade plutonium in irradiated fuel remains at Aqtau).[83] If, over-generously, all seven of the recent sites are considered to have been fully addressed (along with the NTI project at Aqtau), then, by just after the end of FY 2005, material had been removed from 11 of the original 22-24 sites, or 45-50% of the total. If, on the other hand, only those sites are counted where all HEU that poses a significant proliferation threat has been removed, by just after the end of FY 2005 only four sites had been

is no longer located at that facility, it should not be counted against the total number for judging the fraction of facilities that have been addressed.) Some variations in figures may result from differing definitions of "sites" or "facilities" (in Libya, for example, there is both a research reactor and a critical assembly fueled with HEU at a single research institute, so they are counted by some as two facilities and by others as one site); other variations in figures may be caused by differing cutoff times for data.

[82] See discussion of these cases in Matthew Bunn and Anthony Wier, "Removing Material from Vulnerable Sites," in *Nuclear Threat Initiative Research Library: Controlling Nuclear Warheads and Materials* (2004; available at http://www.nti.org/e_research/cnwm/securing/vulnerable.asp as of 2 February 2006).

[83] "Government of Kazakhstan and NTI Mark Success of HEU Blend-Down Project: Material Could Have Been Used to Make up to Two Dozen Nuclear Bombs" (Ust-Kamenogorsk, Kazakhstan: Nuclear Threat Initiative, 2005; available at http://www.nti.org/c_press/release_Kaz_100805.pdf as of 17 January 2006).

completed, roughly 16-18% of the original total.

DOE tracks its progress in returning Soviet-supplied HEU to Russia by the number of kilograms of HEU returned. By the end of FY 2005, 122 kilograms of HEU fuel had been returned to Russia. This represents 6% of the 1,959 kilograms of Soviet-supplied HEU that DOE believes exist outside of Russia.[84] It represents 18%, however, of the fresh, unirradiated Soviet-supplied HEU outside of Russia, and some 60% of the fresh HEU that DOE now expects to be returned to Russia.[85] (DOE now expects that a substantial amount of the fresh HEU in the former Soviet states will be downblended outside of Russia or used as reactor fuel in those states.[86]) The number of kilograms of HEU returned provides a rough measure of the fraction of the work done so far (though irradiated HEU will involve far more costs and difficulties per kilogram than fresh HEU). But it does not provide any insight into whether, for example, particular sites have had all the HEU that could readily be used for a bomb removed, or only a part of it, leaving enough behind to pose a serious proliferation risk. That is why we focus here primarily on the number of sites whose HEU has been entirely removed.

In April 2006, there was a substantial breakthrough in dealing with the irradiated HEU at these sites when DOE announced that the shipment of the irradiated HEU from the Institute for Nuclear Physics in Uzbekistan back to Russia had been completed. This operation demonstrated that the obstacles to returning spent fuel to Russia can be overcome.[87] Moreover, given the political unrest in Uzbekistan and the presence of the Islamic Movement of Uzbekistan, a well-armed terrorist organization linked to al Qaeda, the removal of the HEU from this Uzbek site was particularly important.

There remain significant obstacles to completing the cleanout of Soviet-supplied HEU outside of Russia. Some facilities have not yet agreed to convert to LEU, or to give up the HEU they have on-site. Some countries are willing to give up their HEU stocks, but not to see their HEU sent to Russia; options for blending HEU outside of Russia are being examined (one possibility being to make use of the blending operation at Ulba that blended the Aqtau HEU).

Numbers on how many sites have had all of their U.S.-supplied HEU entirely removed are somewhat fuzzy, as DOE tracks other metrics for its fuel return programs. But it appears that by the end of 2005, all HEU had been removed from something in the range of 10-15 U.S.-supplied sites since 1996 (when the U.S. fuel take-back program resumed).[88]

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[84] The 1,959 kilogram figure is from data provided by DOE, December 2005. This appears to have been updated from the estimate of 1,781 kilograms reported in DOE's budget justifications, prepared earlier. See U.S. Department of Energy, *FY 2007 Defense Nuclear Nonproliferation Budget Request*, p. 562.

[85] Calculated from data provided by DOE, December 2005.

[86] Interviews with DOE officials, December 2005.

[87] U.S. National Nuclear Security Administration, "Secret Mission to Remove Highly Enriched Uranium Spent Nuclear Fuel from Uzbekistan Successfully Completed: Four Shipments Have Been Sent to a Secure Facility in Russia" (Washington, D.C.: NNSA, 2006; available at http://www.nnsa.doe.gov/docs/newsreleases/2006/PR_2006-04-20_NA-06-10.htm as of 16 May 2006).

[88] The Government Accountability Office lists 11 countries which have returned all U.S.-origin HEU. U.S. Congress, Government Accountability Office, *Nuclear Nonproliferation: DOE Needs to Consider Options to Accelerate the Return of Weapons-Usable Uranium from Other Countries to the United States and Russia*, GAO-05-57 (Washington, D.C.: GAO, 2004;

Another way of assessing progress is by the fraction of the HEU that has been returned. As of the end of FY 2005, the assemblies that had been returned, after nine years of the take-back program, contained approximately 1.2 tons of HEU. This represents some 23% of the 5.2 tons of HEU eligible for the program, but only 7% of the 17.5 tons of U.S.-supplied HEU that was abroad when the take-back effort restarted in 1996.[89] In the year since our last report, DOE extended the take-back offer until 2019, and it is therefore not expecting to complete the return of eligible U.S.-supplied HEU until then.

DOE tracks the progress of the effort to take back U.S.-supplied HEU by the total number of fuel assemblies returned to the United States. By the end of FY 2005, this figure stood at 6,783 assemblies returned since the take-back program was restarted in 1996, some 30% of the 22,743 assemblies DOE hopes to return to the United States.[90] These include both LEU assemblies (from reactors that agreed to convert to HEU in the past or were designed from the outset to avoid the use of HEU) and HEU assemblies; indeed, most are LEU assemblies. This metric provides a reasonable rough guide to the fraction of the work accomplished. But by not distinguishing between HEU and LEU, this metric makes it difficult to discern how much of the proliferation threat has been reduced. Like the metric for the Russian take-back effort, it also obscures the issue of how many sites have had all of their HEU removed.

Two-thirds of the 17.5 tons of U.S. HEU that was abroad when the United States renewed its take-back offer in 1996 is not even covered by the U.S. offer to take the HEU back. (The offer was limited at the time to aluminum-based fuels and TRIGA fuels the United States was planning to manage in any case.[91]) This material poses important proliferation risks that are not currently being addressed effectively. The U.S. take-back offer was intended to apply to HEU fuel after it had been used: fresh, unused U.S.-supplied HEU is also a gap material, as is the small amount of HEU supplied by countries other than the United States and Russia, and the research quantities of plutonium that exist at several sites around the world (see discussion of consolidating

available at http://www.gao.gov/new.items/d0557.pdf as of 2 February 2006), p. 9. Some of these countries, however, have HEU from other sources, and some (such as Italy) have U.S.-origin HEU that was not returned because it is not eligible for the current take-back offer. At the same time, however, there are some facilities in other countries that have had all HEU removed from that specific facility, without all HEU having been removed from the country. Additional sources for the estimates here include von Hippel and Glaser data on reactor conversions (personal communication, December 2005), and David Albright and Kimberly Kramer, "Civil HEU Watch: Tracking Inventories of Civil Highly Enriched Uranium," in *Global Stocks of Nuclear Explosive Materials* (Washington, D.C.: Institute for Science and International Security, 2005; available at http://www.isis-online.org/global_stocks/end2003/tableofcontents.html as of 21 May 2006).

[89] Data provided by DOE, December 2005. For the 17.5 tons figure, see, for example, U.S. Department of Energy, Office of the Inspector General, *Audit Report: Recovery of Highly Enriched Uranium Provided to Foreign Countries*, DOE/IG-0638 (Washington, D.C.: DOE OIG, 2004; available at http://www.ig.doe.gov/pdf/ig-0638.pdf as of 3 March 2006). See also U.S. Congress, *Nuclear Nonproliferation: DOE Needs to Consider Options to Accelerate the Return of Weapons-Usable Uranium.* These figures on tons of HEU refer to the tons of HEU the fuel contained when it was originally shipped from the United States; after irradiation, the number of tons of HEU remaining is significantly less. In addition, a modest portion of the total has been reprocessed in Europe and no longer exists as HEU.

[90] U.S. Department of Energy, *FY 2006 Defense Nuclear Nonproliferation Budget Request*, p. 544.

[91] Aluminum-based fuels are being sent to Savannah River, and uranium-zirconium-hydride TRIGA fuels (Training, Research, Isotopes, General Atomics—a common reactor design) are being sent to the Idaho National Laboratory.

civil plutonium stocks below). DOE is currently considering expanding the U.S. take-back program to cover some or all of these "gap materials," in DOE's phrase—meaning materials in the gaps between current programs—but more than two years after the establishment of GTRI, no decision on such an expansion has yet been announced. Nevertheless, GTRI has begun to address some of these gap materials in a small way: by the spring of 2006, for example, 35 kilograms of fresh U.S.-supplied HEU had been returned from Canada and Belgium.[92]

Even the material eligible for the take-back offer is not necessarily fully addressed by current programs. Independent studies have concluded that unless DOE offers greater incentives for facilities to return their HEU to the United States, roughly half the material covered by the take-back offer is not likely to be returned.[93] DOE has not yet spelled out what additional incentives it may be prepared to offer.

**Removing stocks from HEU fuel facilities and other non-research reactor facilities: not yet covered by U.S. programs, in most cases.** Not all civil HEU is at research reactors. As noted above, 41 of the 128 civil sites around the world estimated to possess 20 kilograms or more of HEU are fuel-related facilities. U.S.-sponsored programs have not yet focused on reducing the number of these facilities where HEU is located. If the effort to convert research reactors to LEU is successful, however, there will be less and less demand for HEU fuels and targets, and that will presumably lead fuel facilities to concentrate primarily on making LEU fuels. Nevertheless, targeted efforts to ensure that potentially dangerous stocks of HEU do not remain at these fuel facilities will probably be necessary.

**Avoiding new HEU-fueled research and power reactors: some progress.** Since the effort to convert HEU-fueled research reactors to LEU fuels began in 1978, only one high-power research reactor has been built to use HEU fuel in the Western world, the FRM-II in Germany. Currently, however, Russia is building a new HEU-fueled research reactor, the PIK, in St. Petersburg; Belarus has just started a sub-critical assembly with HEU; and other HEU-fueled reactors are being considered. Russia continues to use HEU fuel (with a maximum enrichment of 26%) in its BN-600 fast-neutron reactor; the BN-800 under construction will probably use plutonium fuel. Early reports indicated that the floating nuclear power plants Russia plans would use HEU fuel, as the submarine reactors the design is based on did, but the Russian government has recently indicated that they will use LEU fuel.[94] Other power reactor concepts in development appear to emphasize the use of LEU or plutonium fuels.

**Consolidating civilian plutonium: not covered by U.S. programs.** Currently plutonium is separated and used for civil purposes on a massive scale in several countries. Roughly 20 tons of plutonium—enough for thousands of nuclear weapons—is separated from spent fuel by civilian reprocessing plants in a typical year, and only about ten tons of that is

[92] U.S. Department of Energy, "GTRI: Two Successful Years of Reducing Nuclear Threats" (Washington, D.C.: DOE, 2006; available at http://www.nnsa.doe.gov/docs/factsheets/2006/NA-06-FS04.pdf as of 21 June 2006).

[93] U.S. Department of Energy, *Audit Report: Recovery of Highly Enriched Uranium Provided to Foreign Countries*. See also U.S. Congress, *DOE Needs to Consider Options to Accelerate the Return of Weapons-Usable Uranium*.

[94] "Russia to Start Building Floating Nuclear Power Plant in 2006," *ITAR-TASS*, 12 January 2006.

used as uranium-plutonium mixed oxide (MOX) reactor fuel. Hence, separated plutonium that is weapons-usable, though reactor-grade, continues to build up in storage. The total quantity of separated civilian plutonium in storage is in the range of 250 tons, roughly equal to all the world's military stockpiles of plutonium combined.[95]

MOX fuel is used in dozens of reactors in several countries in Europe, and Japan plans to begin using it soon. The facilities where the plutonium is separated and fabricated into fuel typically have fairly high levels of security, but some of the reactors where fuel containing large quantities of unirradiated plutonium exists have little more security than other reactor sites. Moreover, transports of large quantities of plutonium oxide from reprocessing plants to fabrication plants, and of MOX fuel from fabrication plants to reactors, occur frequently (particularly in France, which has the largest operating MOX fabrication plant and the largest number of reactors using MOX fuel), and significant concerns have been raised about the security of these transports.[96] While fresh MOX fuel assemblies are large and heavy, making them more difficult to steal, and chemical processing would be needed to extract the plutonium for use in a bomb, a committee of the U.S. National Academy of Sciences recommended that unirradiated MOX fuel, like other forms of plutonium outside of spent fuel, should be protected, to the extent practicable, to the same standards that nuclear weapons themselves are—because acquiring plutonium or HEU is by far the most difficult part of making a nuclear bomb.[97]

As noted in Chapter 2, the Bush administration acknowledged that these stores of fully separated plutonium posed a proliferation threat in presenting its proposal for a Global Nuclear Energy Partnership (GNEP). GNEP would involve reprocessing technology in which the plutonium would never be fully separated, an approach the Bush administration argues would be more proliferation resistant. Critics, however, have challenged whether the processes proposed for GNEP would offer substantial advantages in proliferation resistance.[98] In any case, despite the publicly expressed concerns over the proliferation hazards of these plutonium stockpiles, the U.S. government has no specific policies in place to seek to reduce the number of sites where these stockpiles exist or to limit their growth.

**Developing a rough metric of overall progress.** Information simply does not exist—either in the public domain or in the classified realm—that would make it possible to judge exactly how many buildings, in what countries, require what levels of security upgrades, and therefore to measure accurately what fraction of this job was done. We recommend that the U.S. government seek to compile such a comprehensive assessment, taking into account what is known about all the locations with nuclear warheads and

[95] David Albright and Kimberly Kramer, *Global Stocks of Nuclear Explosive Materials* (Washington, D.C.: Institute for Science and International Security, 2005; available at http://www.isis-online.org/global_stocks/end2003/tableofcontents.html as of 22 February 2006).

[96] See, for example, Timm, *Security Assessment Report for Plutonium Transport in France*.

[97] U.S. National Academy of Sciences, Committee on International Security and Arms Control, *Management and Disposition of Excess Weapons Plutonium* (Washington, D.C.: National Academy Press, 1994; available at http://books.nap.edu/html/plutonium/0309050421.pdf as of 20 March 2006).

[98] Jungmin Kang and Frank Von Hippel, "Limited Proliferation-Resistance Benefits from Recycling Unseparated Transuranics and Lanthanides from Light-Water Reactor Spent Fuel," *Science and Global Security* 13, no. 3 (2005).

weapons-usable materials worldwide, their security levels, and factors affecting the threat in the areas where these facilities exist (from the levels of terrorist and criminal activity to morale, pay, and corruption among the facility staff).

In the absence of such comprehensive data, as a rough metric of progress beyond the former Soviet Union, we will focus on progress in either removing material from or upgrading security at HEU-fueled research reactors (since these are some of the most vulnerable facilities, and also among the facilities for which the most detailed data are available). In this metric, we count any research reactor that has had all of its HEU removed, or has had U.S.-sponsored upgrades completed, as having had the security issues it posed adequately addressed. (This is somewhat over-generous, since, as noted above, the security upgrades being done outside the Soviet Union are only intended to meet rather vague IAEA recommendations, and are not likely to be sufficient to defend these facilities against the threats that exist in many countries.)

**Fraction accomplished.** As noted above, it appears that by the end of FY 2005, the U.S. HEU fuel take-back program had removed all the HEU from 10-15 sites since the take-back effort resumed in 1996, all of which were outside the former Soviet Union. The sites where the Russian take-back effort has succeeded in removing all the HEU have largely been within the Soviet Union, and hence are not counted here; the exception is the VR-1 Sparrow reactor in the Czech Republic. Thus we estimate that these programs have removed all HEU from 11-16 sites outside the former Soviet Union and the United States itself.

As discussed above, U.S.-sponsored security upgrades have been completed for an additional eight sites outside the former Soviet Union – one in China, and seven in other countries performed by the Research Reactor Security program. Thus, 19-24 HEU-fueled research reactor sites outside the former Soviet Union have either had all of their HEU removed or had U.S.-sponsored security upgrades completed.

Today, of the estimated 135 operating research reactors using HEU fuel, roughly 57 are in the former Soviet Union and 24 are in the United States, leaving some 54 reactors in other countries.[99] In the early 1990s, when cooperative threat reduction programs began, this figure was higher, as some reactors have converted or shut-down since then, so the baseline for assessing changes is likely in the range of 60-80 HEU-fueled research reactors outside of the former Soviet Union and the United States in the early 1990s.

In addition to these operating research reactors using HEU at that time, there were other categories of facilities that need to be counted: there were an unknown but probably significant number of reactors that had shut down or converted to LEU but still had significant amounts of HEU on-site; there were the HEU fuel-related facilities discussed above (though many of these are in the United States or Russia); and there were a limited number of civilian sites where significant quantities of HEU existed for other reasons. Including an estimate of these facilities would make the baseline larger, and therefore shrink the fraction of that baseline that has been addressed to date. Nevertheless, to be generous, we will use 60-80 as our baseline estimate of the sites to be addressed.

[99] Data compiled by Frank von Hippel and Alexander Glaser, Princeton University; personal communication, December 2005.

With that baseline, the 19-24 research reactor sites addressed to date represent some 25-40% of the total.

**Rate of progress.** During 2005, security upgrades were completed at one HEU site each in China, at Sevastopol in Ukraine, at Alatau in Kazakhstan, and at Photon in Uzbekistan.[100] For at least two of these sites—Sevastopol and Alatau—these were improvements to security upgrades that had been completed previously, however, so we do not count those as new sites addressed during the year. It appears that only the "Sparrow" reactor at the Czech Technical University had 100% of its HEU removed. While this occurred just after the end of fiscal year 2005, we include it here. Hence it appears that 3 sites either had all of their HEU removed or U.S.-funded security upgrades completed for the first time during the course of the year, representing 4-5% of the original 60-80 sites.

In addition, DOE has already had a major success in FY 2006 with the removal of all irradiated HEU from the Institute of Nuclear Physics in Uzbekistan. During FY 2006 DOE plans to complete security upgrades at several other HEU-fueled reactor sites.

During FY 2005, the number of reactors converted or partly converted increased by only one reactor (from 39 to 40), well short of the target of five additional reactors.[101] It appears, however, that the delays at the other four reactors will be short-lived; indeed, some had converted or were in the process of conversion by the spring of 2006.[102] By the end of FY 2006, DOE hopes to have a total of 46 reactors either converted or partly converted.[103] DOE is unlikely to meet its 2014 deadline for converting 106 reactors, however, unless it gives reactors stronger incentives to agree to convert.

DOE's effort to address Soviet-supplied HEU also fell well short of its target, returning 23 kilograms of HEU to Russia during FY 2005 (bringing the total to 122) rather than the planned 76 kilograms (which would have brought the total to 175).[104] It appears, however, that most of the material that was to have been shipped in FY 2005 will be shipped in FY 2006, along with the material already planned to be shipped in FY 2006; indeed, DOE expects to ship an additional 200 kilograms of fresh Soviet-supplied HEU back to Russia in the last half of FY 2006.[105]

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[100] Data provided by DOE, December 2005. It is somewhat surprising that the Photon site remains a high-priority HEU site; the HEU-fueled reactor at the site was shut down years ago, and Uzbek scientists had previously told U.S. counterparts that all the nuclear material had been removed. Even if that was not the case, the HEU for this liquid-fueled reactor was dissolved in solution, and it would seem to be a simple matter to dilute it with natural uranium so that it would not require the kind of protection that HEU requires. Monterey Institute for International Studies, Center for Nonproliferation Studies, "Uzbekistan Profile: Nuclear Facilities--Photon Radioelectrical Technical Plant," in *Nuclear Threat Initiative Research Library: Country Profiles* (Washington, D.C. and Monterey, Cal.: Nuclear Threat Initiative and Center for Nonproliferation Studies, 2005; available at http://nti.org/e_research/profiles/Uzbekistan/Nuclear/5451_5469.html as of 16 May 2006).

[101] U.S. Department of Energy, *FY 2007 Defense Nuclear Nonproliferation Budget Request*, p. 562. Also data provided by DOE, December 2005, and U.S. Department of Energy, *Performance and Accountability Report: FY 2005*, p. 99.

[102] U.S. Department of Energy, "GTRI: Two Successful Years of Reducing Nuclear Threats."

[103] U.S. Department of Energy, *FY 2007 Defense Nuclear Nonproliferation Budget Request*, p. 562.

[104] U.S. Department of Energy, *FY 2007 Defense Nuclear Nonproliferation Budget Request*, p. 562.

[105] U.S. Department of Energy, "GTRI: Two Successful Years of Reducing Nuclear Threats."

DOE still hopes to return all of the fresh HEU that it expects to be returned to Russia by the end of 2006 (representing another 83 kilograms of HEU).[106] Since last year's report, that goal has been both postponed a year, from 2005 to 2006, and substantially modified, to exclude some 450 kilograms of fresh HEU that states do not wish to return to Russia, and for which other disposition paths will be pursued on a slower schedule.[107] DOE also hopes to complete the return of eligible irradiated Soviet-supplied HEU that has already been discharged from reactors by 2010. After the Bratislava summit, the United States and Russia agreed on a prioritized schedule to meet that objective. Like the fresh HEU objective, however, this target excludes some important stocks of HEU: HEU that is currently being irradiated in reactors or that will be loaded into these reactors in the future will take longer to return.[108] If it ends up taking as long to convert the Soviet-supplied reactors as it does to convert the U.S.-supplied reactors, the last of the Soviet-supplied HEU may not be returned until nearly the 2019 date planned for the U.S.-supplied HEU.

There is no doubt that the pace of removal of Soviet-supplied material has been substantially higher in FY 2004-2005, since the founding of GTRI, than it was in the previous decade, and the post-Bratislava schedule agreement with Russia is a major step. With the completion of the first shipments of irradiated fuel overcoming a long-standing bureaucratic roadblock in Moscow, the odds of meeting the target set in the post-Bratislava joint plan improved. Some of the facilities with Soviet-supplied HEU, however, along with the central governments of the countries in which they are located, remain extremely reluctant to give up their HEU. Substantial packages of positive and negative incentives, pursued at high levels with considerable creativity and perseverance, are likely to be necessary to achieve the 2010 goal.

In contrast, the effort to take back U.S.-supplied HEU somewhat exceeded its target, returning 449 fuel assemblies in FY 2005 rather than the planned 359.[109] During the year, the projected end of the U.S. take-back program was extended by a decade (from 2009 to 2019), a very long period for returning U.S.-supplied HEU. DOE plans to offer countries incentives to return their HEU sooner rather than later, however.

### *Improved Securing Metrics for the Future*

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

- Security must be improved fast enough, so that the security improvements get there before thieves and terrorists do.
- Security must be raised to a high enough level, to make sure that the threats terrorists and criminals have shown they can pose to such sites can be defeated.
- Security must be improved in a way that will last, including after foreign assistance phases out, so that these sites

[106] Data provided by DOE, December 2005.

[107] Data provided by DOE, December 2005.

[108] Data provided by DOE, December 2005. Similarly, GTRI's most recent statement of the 2010 goal refers to completing "all shipments to return eligible Russian-origin HEU spent fuel currently stored outside of reactor cores" by that time. See U.S. Department of Energy, "GTRI: Two Successful Years of Reducing Nuclear Threats."

[109] U.S. Department of Energy, *FY 2007 Defense Nuclear Nonproliferation Budget Request*, p. 562.

do not become vulnerable again in a few years' time.

There are clearly tensions among these three goals: putting in place security systems to defeat larger threats, and security systems that will stand the test of time, inevitably takes longer than slapping together less capable, more temporary systems. Yet meeting all three goals is essential if the objective of keeping nuclear weapons and materials out of terrorist hands is to be met. The metrics discussed in this section really focus only on the first goal, and hence are inevitably incomplete. Moreover, the metrics in this section do not reflect a great deal of other crucial work that is now underway, including: an extensive training program to provide qualified personnel for all aspects of nuclear material security, control, and accounting (including in the key elements of security culture); work with Russian regulators to put in place an effective regulatory program that will give facility managers strong incentives to provide good security; investments to ensure that nuclear material is secure during transport; new computerized national-level systems for real-time accounting for nuclear warheads and materials; and programs to improve personnel reliability checks for people involved in managing or guarding nuclear warheads and materials.

Moreover, even for assessing whether security is improving fast enough, looking only at numbers of buildings or material equipped with modern security and accounting equipment tells only part of the story. General Eugene Habiger, former "security czar" at DOE's nuclear weapons complex and former commander of U.S. strategic nuclear forces, has said: "good security is 20% equipment and 80% culture."[110] Assessing how well programs are doing in changing the crucial "security culture" at these facilities—that is, the degree to which all of the personnel at the site are trained and motivated to maintain high security at all times—is extremely difficult to do, but extremely important.

110 Interview, April 2003.

Ultimately, a balance of a variety of different measures will be needed to get a realistic picture of how much nuclear security is improving. There are a number of plausible metrics for assessing progress toward sustainable security over time.

**The fraction of sites with nuclear security and accounting systems that are performing effectively.** The best single such measure would be one that was performance-based: the fraction of the buildings containing warheads or nuclear material that had demonstrated, in realistic performance tests, the ability to defend against a specified threat. Unfortunately, for nuclear warheads and materials in the former Soviet Union, comprehensive data for such a measure do not yet exist (and even fewer data of this kind are available for nuclear stockpiles in much of the rest of the world). Another indicator of effective performance—in those cases where nuclear regulatory authorities have set effective nuclear security rules and have put in place effective inspection approaches—would be the fraction of facilities that receive high nuclear security marks in regulatory inspections.[111] An even more ambitious approach would be to attempt to assess the overall risk of theft at each site, and then track whether these risks were increasing or decreasing, and by how much. At DOE's own facilities, each facility is required to perform such estimates of overall risk, based on the security system's assessed ability to

111 DOE uses this metric to track the performance of its own nuclear security program. See U.S. Department of Energy, *Performance and Accountability Report: FY 2005*, p. 83.

defeat a specified design basis threat, and on the quantity and quality of nuclear material at the site. If recipient countries undertook similar approaches (possibly with U.S. assistance in doing so), it might be possible to collect at least partial data on whether these overall assessments of risk were increasing or decreasing, and how substantially. Yet another approach would be to assess, for each site, performance in a broad range of areas important to nuclear security and accounting, and then use some form of weighting (based on expert judgment) to provide an overall performance rating—and then track changes in the overall performance rating at different sites.[112]

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

**The presence of stringent nuclear security and accounting regulations that were effectively enforced.** The effectiveness of regulation of nuclear security and accounting could be judged by whether rules have been set which, if followed, would result in effective nuclear security and accounting programs, and whether approaches have been developed and implemented that successfully convince facilities to abide by the rules to a degree sufficient to achieve that objective. Such an assessment would have to rely on expert judgment, other than simply counting a specific number of regulations written, enforcement actions taken, and the like, as such measures of the *quantity* of regulatory action are usually almost unrelated to the actual *effectiveness* of regulation.[113] Surveys of managers and other personnel at nuclear sites about their experience with regulators and inspectors, and with enforcement and other approaches to encouraging compliance, could also be helpful in assessing the effectiveness of regulations.

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

**The presence of strong "security cultures."** Effective organizational cultures are notoriously difficult to assess, but critically important. Ideally, nuclear security culture should be measured by actual day-in, day-out behavior—but developing effective indicators of day-to-day security performance has proven difficult. Potential measures of *attitudes* that presumably influence behavior include the fraction of security-critical personnel who believe there is a genuine threat of nuclear theft (both by outsiders and by

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

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

insiders), the fraction who understand well what they have to do to achieve high levels of security, the fraction who believe that it is important that they and everyone else at their site act to achieve high levels of security, the fraction who understand the security rules well, and the fraction who believe it is important to follow the security rules. Such attitudes could be assessed through surveys, as is often done to assess safety culture—though enormous care has to be taken in designing the specifics of the approach, to avoid employees simply saying what they think they are supposed to say.[114]

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

In 2001, DOE's MPC&A program took a first cut at the complex task of developing appropriate metrics to assess the real state of progress toward achieving sustainable security at former Soviet sites.[115] The program is now putting a substantial focus on progress toward strong security cultures and long-term sustainability as part of developing a new strategic plan. But there is still more to be done to develop performance measures that adequately reflect the real state of progress, but are simple enough to be useful to policy-makers.

[114] For a brief discussion of such safety culture surveys, see International Atomic Energy Agency, *Safety Culture in Nuclear Installations: Guidance for Use in the Enhancement of Safety Culture*, IAEA-TECDOC-1329 (Vienna: IAEA, 2002; available at http://www-pub.iaea.org/MTCD/publications/PDF/te_1329_web.pdf as of 28 March 2006).

[115] U.S. Department of Energy, *MPC&A Program Strategic Plan* (Washington, D.C.: DOE, 2001; available at http://www.nti.org/e_research/official_docs/doe/mpca2001.pdf as of 7 March 2005), pp. 26-28.

## Tracking Progress: Interdicting Nuclear Smuggling

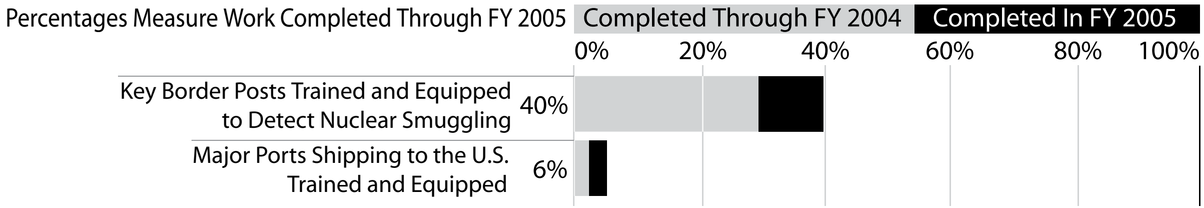
Developing metrics for the goal of interdicting nuclear smuggling is difficult, as many different elements are essential to accomplishing the overall goal. These include, among other steps: providing adequate capabilities to detect nuclear materials being smuggled across borders; establishing appropriate police and intelligence units in the relevant countries that are trained and equipped to deal with nuclear smuggling cases; creating stronger legal infrastructures so that nuclear thieves and smugglers face a greater chance of a larger punishment; expanding international intelligence and police cooperation focused on finding and arresting those involved in nuclear smuggling; and carrying out stings and other operations designed to break up nuclear smuggling rings and make it more difficult for thieves and buyers to reliably connect with each other.[116]

Two steps that are necessary but not sufficient to accomplishing the goal are to ensure that:

- at least the most critical border crossings in the key source and transit states for nuclear material have personnel trained and equipment designed to detect smuggled nuclear materials; and
- major ports and other locations shipping cargo to the United States and major ports and other entry points into the United States are equipped to be

[116] For a discussion, see, for example, Anthony Wier, "Interdicting Nuclear Smuggling," in *Nuclear Threat Initiative Research Library: Controlling Nuclear Warheads and Materials* (2002; available at http://www.nti.org/e_research/cnwm/interdicting/index.asp as of 1 March 2006).

**Figure 3-3**
**How Much Interdicting Work Have U.S.-Funded Programs Completed?**




able to detect smuggled nuclear weapons or materials.

Measuring progress in these two areas provides a rough guide as to how much initial progress in addressing nuclear smuggling has been accomplished, but many of the complex suite of activities involved in interdicting nuclear smuggling are not captured by these metrics. Official border crossings are only a tiny fraction of the thousands of miles of border across which nuclear material might be smuggled, and many seizures of stolen nuclear material have occurred within countries, not at borders, as a result of effective police and intelligence work.

UNSCR 1540 obliges all states to put in place "appropriate effective" border and export controls and law enforcement efforts to prevent illicit trafficking in nuclear weapons-related material. As we have discussed in earlier reports, we believe the U.S. government should work with other states to define the essential elements of appropriate effective border and export controls and then evaluate whether states have put those measures in place, offering assistance where states need help in doing so.[117]

Export control and nuclear smuggling interdiction are two different activities (though they overlap to some degree).

[117] For more on possible measures, see Bunn and Wier, *Securing the Bomb 2005*, pp. 47-49.

Nevertheless, the measures used by the State Department's Export Control and Related Border Security (EXBS) Assistance program offer a useful analogy. EXBS annually assesses the number of the national export control systems receiving State Department assistance that meet "international standards."[118] By the end of FY 2005, the EXBS program had graduated Poland, Hungary, the Czech Republic, and two other countries into a "limited sustainment" phase of the State Department export assistance program. By the end of FY 2006, the State Department expects that the export control systems of three more countries will reach the international level.

Given the many dimensions of an effective national export control system, these assessments are necessarily complex, and appear to focus primarily on the degree to which various elements judged to be essential to an effective overall system are present, more than how effective on-the-ground enforcement really is.[119]

[118] U.S. Department of State, *FY 2007 Congressional Budget Justification for Foreign Operations* (Washington, D.C.: U.S. Department of State, 2005; available at http://www.state.gov/documents/organization/60647.pdf as of 20 March 2006), p. 135.

[119] For a discussion of an early version of the University of Georgia's approach to evaluating export control systems, see Gary Bertsch and Michael Beck, *Nonproliferation Export Controls: A Global Evaluation* (Athens, Georgia: Center for International Trade and Security, The University of Georgia, 2000; available at http://www.uga.edu/cits/documents/html/nat_eval_execsumm.htm as of 7 March 2006).

### *Interdicting Metric 1: Key Border Posts Trained and Equipped to Detect Nuclear Smuggling*

**Fraction accomplished.** Understanding how many sites should be considered high priorities for installing nuclear detection equipment is itself a difficult task, though in recent years DOE has provided much more information about the number of border crossings equipped and trained. Currently DOE's Second Line of Defense program anticipates installing radiation detection equipment at approximately 350 sites around the world (updated from an estimated target of 330 in February 2005).[120] Of these, approximately 120 are at Russian points of entry (Russian customs officials have installed portal monitors at approximately 120 other sites, and plan to install equipment at another 110 sites, totaling approximately 350 international points of entry in Russia). The remaining 230 sites currently targeted by DOE are located in 29 other countries.[121] By the end of FY 2005, DOE had completed providing equipment and training for 83 "core" Second Line of Defense program sites (excluding two megaports, which are noted below).[122] Seventy eight of the sites are in Russia, four are in Greece (these were installed in connection with preparations for the 2004 Olympics), and one is in Lithuania.[123]

During FY 2005, DOD's Weapons of Mass Destruction Proliferation Prevention Initiative completed portal monitor and related installation at the first 11 sites in Uzbekistan, out of 17 anticipated sites (DOD efforts in other countries have provided handheld radiation detection equipment; in Ukraine, DOD is complementing, with training and additional equipment, DOE efforts to install radiation detection at key points of entry).[124] DOE has also taken over maintenance of radiation portal monitors and mobile x-ray and gamma detection vans located at approximately 75 sites in 21 countries, originally provided by the State Department.[125] Also, the State

[120] This figure represents the total set of sites that are to be equipped with radiation detection equipment—though there are some additional border crossings in these key countries that are not included. Interviews with DOE officials, February 2003. The February 2005 figure is from U.S. Department of Energy, *FY 2006 Defense Nuclear Nonproliferation Budget Request*, p. 485. The current figure is from U.S. Department of Energy, *FY 2007 Defense Nuclear Nonproliferation Budget Request*, p. 514.

[121] See David Huizenga's written testimony in Homeland Security and Governmental Affairs Committee, Permanent Subcommittee on Investigations, *Hearing on Nuclear and Radiological Threats*, U.S. Senate, 109th Congress, 2nd Session (28 March 2006; available at http://hsgac.senate.gov/index.cfm?Fuseaction=Hearings.Detail&HearingID=335 as of 30 March 2006).

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

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

[124] For the WMD-PPI programs in Ukraine and Uzbekistan, see U.S. Department of Defense, *FY 2007 CTR Annual Report*, pp. 39-41.

[125] For site count, interviews with DOE officials, April 2006. Portal monitors were installed by the State Department in the Czech Republic, Slovakia, Romania, Bulgaria, Estonia, Latvia, Lithuania, Ukraine, Azerbaijan, Georgia, Turkmenistan, and Kazakhstan. X-ray/gamma-detecting vans were provided by State to Slovenia, Hungary, Poland, Moldova, Armenia, Uzbekistan, and Kyrgyzstan, along with the Czech Republic, Slovakia, Romania, Bulgaria, Estonia, Latvia, Lithuania, Azerbaijan, and Kazakhstan. The State Department also installed radiation portal monitors in Turkey, but DOE is not maintaining that equipment at the request of the Turkish government. DOD provided portal monitors to Belarus, but current U.S. policy prevents DOE from maintaining that equipment. U.S. Congress, Government Accountability Office, *Combating Nuclear Smuggling: Corruption, Maintenance, and Coordination Problems Challenge U.S. Efforts to Provide Radiation Detection Equipment to Other Countries*, GAO-06-311 (Washington, D.C.: GAO, 2006; available at http://hsgac.senate.gov/_files/GAOREPORTInternational.pdf as of 30 March 2006), pp. 45-48.

Department funded installation of portal monitors at a site in Armenia (across from a site in Georgia where DOE plans to install monitors, thus providing a redundant system to confront possible corruption). The State Department and DOD both may target additional sites for assistance, in coordination with DOE.[126]

All told, it appears likely that through FY 2005 the fraction of the identified set of priority border crossings that have been provided with appropriate equipment and trained personnel is in the range of 40%, as shown in Figure 3-3.[127]

As with securing weapons or materials, however, just because a site has U.S.-provided equipment and training does not mean that it is necessarily invulnerable to nuclear smuggling. Much of the equipment that has been installed would likely have difficulty detecting shielded HEU. Moreover, equipment must be maintained and used effectively, and border officials must be honest and alert, for illicit nuclear shipments to be stopped. In a March 2006 report, the Government Accountability Office (GAO) noted that the equipment provided by the State Department was less sophisticated in its detection capability than the equipment provided by the DOE Second Line of Defense program (detecting gamma radiation, instead of both neutron and gamma radiation).[128] DOE officials have stated that by the end of FY 2007 it will overhaul with complete upgrade suites (that is, including communication links and other improvements) those sites that fit into the DOE plan; otherwise by the end of FY 2007 it will upgrade the portal monitors installed by the State Department to dual-channel gamma and neutron detectors, and then add the full suite later.[129]

With corruption among customs officials often widespread, U.S. programs are providing anti-corruption training for customs officers. In addition, the DOE and DOD programs are deploying communication packages with their detection systems that would notify a central command center when an alarm occurs or when a portal monitor is shut off, making it more likely that a border customs guard would be caught if he or she tried to let someone bypass the detection system.[130]

**Rate of progress.** Using the target number of sites identified above, we estimate that approximately 30% of the key border sites had radiation detection equipment installed by the end of FY 2004, meaning that approximately 10% of the sites were completed in FY 2005.[131]

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[126] For a discussion on State plans, see U.S. Congress, *Combating Nuclear Smuggling: Problems Challenge U.S. Efforts*, pp. 14-16. On DOD, see U.S. Department of Defense, *FY 2007 CTR Annual Report*, p. 42.

[127] As a baseline, we use the estimate of 350 sites targeted by DOE, 17 sites targeted in Uzbekistan by DOD, and 75 sites where assistance has been provided by the State Department, for a total of 442 sites.

[128] U.S. Congress, *Combating Nuclear Smuggling: Problems Challenge U.S. Efforts*, pp. 18-20.

[129] Interview with DOE officials, April 2006. Also, *Hearing on Nuclear and Radiological Threats*.

[130] U.S. Congress, *Combating Nuclear Smuggling: Problems Challenge U.S. Efforts*, pp. 16-18.

[131] In last year's report, based on the data we had available at the time, we put this figure at 25%, rather than 30%. Bunn and Wier, *Securing the Bomb 2005*, pp. 45-47. At that time, the government had not yet provided data on the number of individual sites addressed by State Department work for which DOE had inherited maintenance responsibilities, and our estimate was only 21, for the 21 countries where this equipment is located, rather than the approximately 75 sites that DOE now reports it inherited from the State Department. Last year's figure also differs because of the increase in the government's estimate of the total number of sites to be addressed.

By the end of FY 2004, DOE reports that it had completed installations at 64 sites (59 in Russia, 4 in Greece, and 1 in Lithuania); thus, DOE completed 14 sites in FY 2005, though it had hoped to install equipment at 29 sites.[132] It had trouble completing implementing agreements with Georgia, Slovenia, Azerbaijan, Ukraine, and Kazakhstan, thus delaying installations of equipment until at least FY 2006.[133] With agreements completed with all of those countries except Kazakhstan, DOE expects to complete 21 border sites in FY 2006, bringing the total up to 104.[134]

### *Interdicting Metric 2: Major Ports Shipping to the United States Trained and Equipped to Detect Nuclear Smuggling*

**Fraction accomplished.** There are some 6,000 shipping ports worldwide, roughly 700 of which ship directly to the United States.[135] The United States, in the aftermath of the September 11 attacks, has attempted to "push the borders out" with programs designed to make sure that cargo is examined appropriately before it ever reaches U.S. shores.[136] This is particularly important in the case of possible smuggling of a crude nuclear bomb: inspections after the ship holding the bomb has already arrived at the port in New York or Los Angeles or other U.S. cities could be too late, with the bomb detonating before the inspection occurred and causing horrifying damage. Hence, the U.S. government has launched a "Megaports Initiative," in support of the broader "Container Security Initiative," to equip with radiation detection equipment those ports that generate the largest volumes of shipping headed for the United States. DOE has developed a Maritime Prioritization Model that now identifies 64 ports at which the Megaports Initiative hopes to work.[137] The model looks at total container traffic coming into the United States, at the regional threat, and at factors such as how most containers enter the port (via trucks directly or from other ports).[138] Some ports tend to have more container traffic that enters the port via truck or rail, while others are mainly transshipment ports, in which containers are brought in on one ship and sent off on another; the Megaports Initiative targets both types of ports, looking for choke points in the port operations to scan containers.

By the end of FY 2005, DOE had completed installation of radiation detection equipment at ports in four countries: Rotterdam in the Netherlands, Piraeus in Greece, Colombo in Sri Lanka, and a pilot project at Freeport in the Bahamas.[139] This

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

[133] U.S. Congress, *Combating Nuclear Smuggling: Problems Challenge U.S. Efforts*.

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

[135] Interview with DOE officials, April 2006.

[136] U.S. Department of Homeland Security, *A National Cargo Security Strategy White Paper*, Draft Version 1.8 (Washington, D.C.: DHS, 2004; available at http://www.homelandsecurity.org/bulletin/White_Paper_12-09-04_ver__1_8.pdf as of 1 June 2006).

[137] U.S. Department of Energy, *FY 2007 Defense Nuclear Nonproliferation Budget Request*, p. 514. In recent testimony, a DOE official cited the number as approximately 70 ports, in 35 countries; see *Hearing on Nuclear and Radiological Threats*. It is not clear if this is a revision of the target, or just rounding up of the figure of 64.

[138] U.S. Congress, Government Accountability Office, *Preventing Nuclear Smuggling: DOE Has Made Limited Progress in Installing Radiation Detection Equipment at Highest Priority Foreign Seaports*, GAO-05-375 (Washington, D.C.: GAO, 2005; available at http://www.gao.gov/new.items/d05375.pdf as of 30 March 2006), p. 11.

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

represents some 6% of the 64 ports DOE expects to target for these installations, as shown in Figure 3-3. By the spring of 2006, DOE reported that systems were operational at two more ports, at Algeciras in Spain and in Singapore.[140]

**Rate of progress.** By the end of FY 2004 the Megaports Initiative had completed work in 3% of the ports targeted, so an additional 3% were completed in FY 2005.

DOE had expected to have nuclear detection operational at 5 of the 64 megaports targeted by the end of FY 2005, but as noted above, the fifth port was not completed until spring of 2006. DOE has completed agreements to install equipment in eight other countries (Belgium, China, the United Arab Emirates, Honduras, Israel, Oman, the Philippines, Singapore, and Thailand). Beyond Spain, DOE expects to complete work at four ports in those countries by the end of FY 2006, bringing the total by that date to ten ports, or 16% of the ports targeted. Barring any expansion of the number of targeted sites, DOE anticipates completing radiation detection equipment installations at the 64 targeted ports by the end of calendar year 2013.[141]

### *Improved Interdicting Metrics for the Future*

As noted above, interdicting nuclear smuggling requires a broad complex of activities, many of which are not included in metrics focused on the fraction of key border sites and ports trained and equipped to detect nuclear contraband. In particular, official border crossings are only a tiny fraction of the thousands of miles of border across which nuclear material might be smuggled, and many seizures of stolen nuclear material have occurred within countries, not at borders, as a result of effective police and intelligence work.

Hence, we believe the U.S. government should also track measures including both the fraction of countries considered key source or transit countries that have at least one unit of the national police trained and equipped to deal with nuclear smuggling cases (and which have informed the rest of the nation's law enforcement personnel about how to involve that unit when such a case arises), and the fraction of those key source or transit countries that have established in-depth intelligence and law enforcement sharing on nuclear smuggling with the United States, with each other, and/or with international agencies. As with securing nuclear stockpiles, measures of actual effectiveness would be even more telling indicators of how much real progress had been made. In the United States, for example, security at airports is often checked by government testers attempting to smuggle knives, guns, or explosives through security checkpoints. One could imagine contracting for testers to attempt to smuggle nuclear material through border crossings that had been equipped with radiation detectors, tracking the percentage of the time they were detected as one measure of progress. At the national level, an interesting measure of effectiveness to track would be the percentage of nuclear or radiological smuggling cases in which all the conspirators were identified and brought to justice, though these cases, fortunately, are rare enough in any particular country

[140] U.S. Department of Energy, National Nuclear Security Administration, *Fact Sheet on NNSA's Second Line of Defense Program* (Washington, D.C.: DOE, 2006; available at http://www.nnsa.doe.gov/docs/factsheets/2006/NA-06-FS01.pdf as of 7 March 2006).

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

that this percentage might vary randomly a great deal.

Alternatively, it would be desirable to establish and track more complex sets of measures of the overall effectiveness of each country's measures to prevent nuclear smuggling on its territory, comparable to the assessments of export control effectiveness used by the State Department's EXBS program, discussed above. Widely publicizing the full results of each year's assessment might not be appropriate because it might highlight specific, exploitable deficiencies in particular countries' systems, but releasing summary evaluations of the performance of countries' efforts to stop nuclear smuggling systems should not pose any significant risk. At an absolute minimum, relevant policy-makers in the executive and legislative branches should have access to the assessments, and, as a management tool, should examine links between countries' year-to-year performance on the assessment and the resources spent in those countries.

## Tracking Progress: Stabilizing Employment for Nuclear Personnel

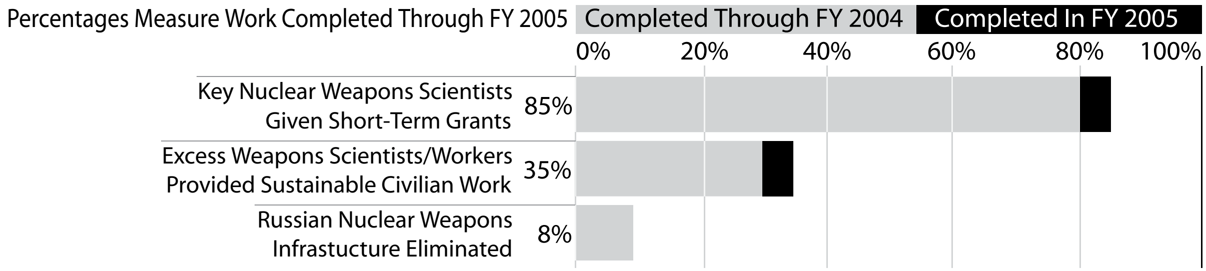
Measuring the impact of U.S. attempts to alter the incentives facing personnel with access to nuclear weapons, materials, and expertise is highly challenging.[142] There are multiple conceptions of the threat such programs are designed to address (e.g., scientists emigrating to a proliferating state, insiders helping a terrorist group, whole facilities collaborating with outside regimes, or countries calling upon their weapons infrastructure to expand weapons programs). Indeed, the same programs may be asked to address multiple types of threats. For instance, addressing the problem of intellectual proliferation in the vast nuclear complex left to the former Soviet states, after a decade of economic transition and government-to-government collaboration, is certainly a different task than targeting the relatively limited number of scientists with critical proliferation knowledge who are trying to adjust to a dangerous, uncertain future in post-Saddam Iraq; nevertheless, the State Department's Nonproliferation of WMD Expertise program is nevertheless dealing with both scenarios.[143]

Developing metrics in this area is particularly difficult, because data on just how many knowledgeable scientists, engineers, and technicians should be targeted by U.S. programs are murky at best. Partner countries are necessarily secretive about participants in their former weapons programs. U.S. programs will never be able to reduce to zero the probability that a scientist or scientists in a targeted country will lend their assistance to other states or to terrorists, so assessing when U.S. help is no longer necessary will always be a challenge. Perhaps even more than in the securing task, developing recipients' ability to sustain improvements in the economic situation of nuclear personnel is critical. Building scientists' and their insti-

[142] For longer discussions on measurement issues, see Bunn and Wier, *Securing the Bomb: An Agenda for Action*, pp. 64-72; Matthew Bunn, Anthony Wier, and John Holdren, *Controlling Nuclear Warheads and Materials: A Report Card and Action Plan* (Cambridge, Mass., and Washington, D.C.: Project on Managing the Atom, Harvard University, and Nuclear Threat Initiative, 2003; available at http://www.nti.org/e_research/cnwm/overview/report.asp as of 1 February 2006), pp. 75-78.

[143] The original philosophy in coping with Russia, namely, tiding over scientists to stave off desperation, drove the opening phase of interaction with Iraqi former WMD scientists, though even the latter effort appears to be broadening; see U.S. Department of State, *FY 2007 Congressional Budget Justification for Foreign Operations* (Washington, D.C.: U.S. Department of State, 2006; available at http://www.state.gov/documents/organization/60647.pdf as of 20 March 2006), p. 143.

***Figure 3-4***
***How Much Stabilizing Work Have U.S.-Funded Programs Completed?***




tutes' capacity to sustain their own work has thus long been integral to U.S. efforts.

One of the few systematic studies of the recipients of U.S. assistance seems to confirm that U.S.-funded grants for former weapons scientists do reduce the recipients' willingness to help developing countries with mass destruction programs, thus reducing proliferation risks. The survey, conducted in 2002 and 2003, found that Russian scientists who had received even short-term grant assistance from a Western program were significantly less likely to say they would be willing to work for a state of proliferation concern than those who had not received such assistance.[144]

In the discussion below, we will focus on three simple measures of progress in these programs: the fraction of the key nuclear weapon scientists who have received short-term grants; the fraction of excess nuclear weapon scientists and workers provided with sustainable civilian employment for the long haul; and the fraction of Russia's nuclear weapons infrastructure eliminated. Particularly for the first two measures, data are admittedly incomplete, but the measures give the reader at least a rough guide to the scope of work completed and remaining. We try to distinguish between what U.S.-funded programs can take credit for, and what has been accomplished through Russia's own efforts or those of others.

Our measures continue to focus on the former Soviet Union, because new programs focused on redirecting weapons scientists in Iraq and Libya are very small in comparison to the massive former Soviet complex, and because those programs have provided too little public information to understand what fraction of their mission the Iraqi and Libyan efforts have completed. It is worth noting that beyond Iraq and Libya, the State Department's Nonproliferation of WMD Expertise program has stated its intention for FY 2007 to expand its program "to engage scientists, engineers, and technicians in key regional areas who have dual-use expertise that could be easily applied to WMD."[145] The

[144] Deborah Yarsike Ball and Theodore P. Gerber, "Russian Scientists and Rogue States: Does Western Assistance Reduce the Proliferation Threat?" *International Security* 29, no. 4 (Spring 2005). Because those who had sought Western assistance but received no funding held attitudes about working for a proliferating state similar to those who did not seek Western assistance in the first place, the authors of the study conclude that the attitudes of the grant recipients were a result of their Western interaction, and not a reflection of their willingness to seek Western assistance. Oddly, receiving similar grants from Russian sources did not have a significant effect on these attitudes, suggesting that the effect of these programs related both to the money received and the connection to the West resulting from them.

[145] U.S. Department of State, *FY 2007 Congressional Budget Justification for Foreign Operations*, p. 139.

program has not specified which "key regional areas" it intends to target.

### *Stabilizing Metric 1: Key Nuclear Weapons Scientists Given Short-Term Grants*

**Fraction accomplished.** Using available anecdotal information, in our previous reports we concluded that it was likely that in the nuclear sector at least, the International Science and Technology Centers in Moscow (ISTC) and Ukraine (STCU), the Initiatives for Proliferation Prevention (IPP), or similar projects have provided grants to a very large fraction—perhaps 80% or more—of those nuclear scientists and technicians most in need and seeking assistance.[146] Such anecdotal evidence was supported by the same survey of Russian nuclear, chemical, and biological scientists noted above, which found that fewer than 20% of those scientists who had sought Western grant assistance had failed to receive any.[147] In fact, the survey's reported percentages are likely too high for the nuclear field, because the study's authors were unable to include scientists at nuclear weapons research institutes—which have been heavily targeted by ISTC, IPP, and DOE's Nuclear Cities Initiative (NCI)—and because the survey's results had been calibrated to reduce the over-representation of nuclear scientists, the field receiving the most foreign attention thus far. (Despite a heightened focus by U.S. programs in the last several years, the fraction reached by grant assistance is likely less in the chemical and biological areas; important progress is being made in those areas.[148])

By the end of FY 2005, DOE reports that IPP and NCI, the two efforts that make up the Global Initiatives for Proliferation Prevention (GIPP), employed 11,500 scientists and technicians either through DOE-funded grants or in long-term private sector jobs enabled by such grants.[149] That 11,500 figure for FY 2005 compares to 11,200 for FY 2004, a difference of 300. DOE said it is targeting 17,000 people for such employment by 2015. It bases that target on an estimate of 60,000 experts originally requiring attention less attrition among the working target population and the experts reached by ISTC, STCU, or other efforts.

The State Department's Nonproliferation of WMD Expertise program, which is the lead U.S. agency supporting ISTC and STCU, no longer reports on how many individuals its efforts have reached (the most recent period the State Department reported on individual experts was for FY 2003, when it said it had engaged about 26,000 former weapons scientists over the course of its work).[150] The State Department instead focuses on the number of "proliferation-relevant" institutes or groups of scientists "engaged." By the end of FY 2005, the State Department reports that it has provided assistance to some 469 Russian and other Eurasian institutes or groups, up from 460 in FY 2004

[146] Bunn and Wier, *Securing the Bomb: An Agenda for Action*, p. 68; Bunn, Wier, and Holdren, *Controlling Nuclear Warheads and Materials: A Report Card and Action Plan*, pp. 74-77.

[147] There were also nearly 40% of the scientists surveyed who had never sought such assistance; see Ball and Gerber, "Russian Scientists and Rogue States."

[148] U.S. Department of State and U.S. Agency for International Development, *FY 2007 Performance Summary* (Washington, D.C.: U.S. Department of State, 2005; available at http://www.state.gov/s/d/rm/rls/perfplan/2007/pdf/ as of 4 April 2006).

[149] U.S. Department of Energy, *FY 2007 Defense Nuclear Nonproliferation Budget Request*, p. 497.

[150] U.S. Department of State and U.S. Agency for International Development, *FY 2007 Performance Summary*, p. 84.

and 430 in FY 2003.[151] Many of the institutes newly engaged appear to focus on chemical or biological work, as opposed to nuclear-related research, which had been the focus in the earlier years of the effort. Unlike DOE, the State Department declines to define the scope of the target population it hopes to reach.

Last year we did not change our estimate of progress from the year before. Given that the efforts at both the State Department and DOE are reporting that they have reached out to additional scientists, it is reasonable to revise our estimate upward. We therefore estimate that some 85% of the key nuclear weapons scientists targeted have received short-term grants, as noted in Figure 3-4.

**Rate of progress.** On this metric (if not on others) the effort in the nuclear sector has largely stabilized, though U.S. programs have identified no clear target for ending grant assistance. While it does appear that there was slight progress in the past year in reaching a few more weapons experts, it is not clear how many key former Soviet nuclear scientists have not yet been reached by foreign grant assistance, with the exception of those at the warhead assembly/disassembly facilities.

### *Stabilizing Metric 2: Excess Nuclear Weapon Scientists and Workers Provided Sustainable Civilian Work*

**Fraction accomplished.** As we have discussed at length in our previous reports, creating sustainable civilian employment for former Soviet weapons scientists remains an important measure of success for U.S. efforts to stabilize nuclear personnel.[152] GIPP, which contains both the NCI and IPP, and the State Department's Nonproliferation of WMD Expertise program (particularly through support of the ISTC and STCU program to partner with foreign companies) have directly supported creating commercial operations based on technologies and expertise drawn from the weapons complex.

These are not the only governmental and nongovernmental efforts creating employment for excess nuclear weapon experts, however. For instance, NCI supplied seed money to set up European Bank for Reconstruction and Development (EBRD) loan programs in the Russian nuclear cities Sarov, Snezhinsk, Zheleznogorsk, and Seversk.[153] These programs have made over a thousand small-business loans in these cities, presumably supporting the creation of thousands of new jobs in these towns, some of which may be held by former employees of the nuclear weapons complex. Other U.S.-funded programs not directly focused on job creation, such as the U.S.-Russian HEU Purchase Agreement, the MPC&A program, and initiatives to develop new monitoring and detection technologies and procedures, have also led to the creation of large numbers of jobs. Other U.S.-supported efforts to improve the business climate and promote general economic development in Russia's nuclear cities, such as the International Development Centers in Zheleznogorsk and Snezhinsk, might

[151] See the description for the Nonproliferation of WMD Expertise program in U.S. Office of Management and Budget, *Program Assessment Rating Tool*.

[152] For our earlier discussions of metrics for stabilizing employment for nuclear personnel, see Bunn and Wier, *Securing the Bomb 2005*, pp. 53-56; Bunn and Wier, *Securing the Bomb: An Agenda for Action*, pp. 68-72; Bunn, Wier, and Holdren, *Controlling Nuclear Warheads and Materials: A Report Card and Action Plan*, pp. 74-77.

[153] See also, Sharon K. Weiner, "Preventing Nuclear Entrepreneurship in Russia's Nuclear Cities," *International Security* 27, no. 2 (Spring 2002), p. 156.

also help add to job growth that could absorb former nuclear weapons workers. Privately financed initiatives have also created substantial numbers of jobs for former nuclear workers.[154] In addition, other countries, through the G8 Global Partnership, help contribute to job creation.[155] Though there clearly has been some contribution, specific numbers of jobs created by these endeavors are unknown. Nevertheless, to the extent all of these initiatives, plus Russia's own efforts, create sustainable, long-term jobs, the total requirement for jobs to be created by U.S. efforts is reduced.

DOE estimates that by the end of FY 2005, the programs included in GIPP had helped create 3,800 long-term jobs, out of a population of 11,000 displaced former Soviet weapons experts for whom DOE hopes to find employment by FY 2019.[156]

The State Department does not provide performance data on the number of jobs created for former weapons experts. Instead, it reports that, as of FY 2005, 27 institutes or groups of scientists have "graduated" into "commercially sustainable ventures."[157] Because the State Department has not published a list of which institutes have graduated or the average number of scientists employed at these institutes, it is difficult to estimate what fraction of these institutes focused on nuclear technologies, and how many former nuclear weapon experts may be employed in these new commercial ventures.

In last year's report, we estimated that, through a combination of jobs added by direct U.S. efforts and jobs created in some other manner (which reduce the total number of jobs that need to be provided to address the proliferation problem), the various U.S.-funded initiative might have created approximately 30% of the roughly 15,000-20,000 jobs that might be needed to cope with the downsizing of Russia's nuclear complex (while acknowledging that this might overestimate progress, as many of these jobs might not be held by personnel from key positions in the nuclear weapons complex). With the further progress reported by DOE and the State Department this year, we estimate that U.S.-funded programs have now provided some 35% of the necessary sustainable civilian employment for personnel from Russia's nuclear weapons complex.

**Rate of progress.** The publicly available data on the total number of jobs provided for former nuclear weapons scientists and workers in the last year are very limited, but that number appears unlikely to have been more than 5% of the total need. DOE reports that during FY 2005 its efforts created sustainable employment for 300 former Soviet weapons experts. For FY 2006, GIPP is hoping to

[154] These includes independent ventures by private companies, as well as work supported by non-governmental operations such as the Nuclear Threat Initiative; see Bunn and Wier, *Securing the Bomb: An Agenda for Action*, p. 70.

[155] For more on G8 nations' efforts, see Center for Strategic and International Studies, "Donor Fact Sheets: Scientist Employment," in *Strengthening the Global Partnership Project* (Washington, D.C.: CSIS, 2004; available at http://www.sgpproject.org/Donor%20Factsheets/ProjectAreas/SciEmploy.html as of 9 March 2006). Also, see the 2005 official report of G8 donors, at *GPWG Annual Report 2005: Consolidated Report Data (Annex A)* (Gleneagles, United Kingdom: G8 Summit, 2005; available at http://www.sgpproject.org/resources/Gleneagles/AnnualReport2005.pdf as of 23 June 2006).

[156] U.S. Department of Energy, *FY 2007 Defense Nuclear Nonproliferation Budget Request*, p. 497.

[157] See the description for the Nonproliferation of WMD Expertise program in U.S. Office of Management and Budget, *Program Assessment Rating Tool*.

create sustainable jobs for another 300 experts. The State Department reports that 3 institutes graduated from the assistance program, up from 24 at the end of FY 2004.[158] Through FY 2007, the State Department hopes to graduate 2-3 more institutes per year.[159]

### *Stabilizing Metric 3: Russian Nuclear Weapons Infrastructure Eliminated*

**Fraction accomplished.** Russia's nuclear weapons complex remains far too large to support Russia's current nuclear stockpile (estimated at some 16,000 total warheads, including 7,200 active warheads), much less for a smaller stockpile of around 5,000-6,000 strategic, tactical, and reserve warheads that would be consistent with Russia's obligations under the 2002 Strategic Offensive Reductions Treaty.[160] In last year's report, we assumed as a target for U.S. downsizing assistance programs a Russian nuclear weapons complex that was focused in four closed cities (and a few facilities in open cities), and that would employ about 30,000 people (a difference of about 45,000 employees from the weapons complex as it existed in 2000).[161]

Only one U.S. program, NCI, is specifically focused on supporting Russia in closing down excess nuclear weapons-related facilities; to do so it seeks to alleviate Russian reluctance to downsize facilities by fostering viable local civilian alternatives to which the facility and its employees might turn. Though the formal NCI intergovernmental agreement expired in 2003, the program has continued to support projects approved before the agreement expired, and has sought to direct money for new projects through the ISTC.[162]

NCI has set nuclear weapons complex reduction targets for six Russian nuclear weapons complex sites, including two nuclear weapons assembly-disassembly facilities (Avangard in Sarov and Zarechnyy), two plutonium production facilities (Seversk and Zheleznogorsk), and two weapons design institutes (VNIIEF at

[158] U.S. Office of Management and Budget, *Program Assessment Rating Tool*.

[159] U.S. Department of State and U.S. Agency for International Development, *FY 2007 Performance Summary*, p. 84.

[160] Estimates of the warhead stockpile size come from Robert S. Norris and Hans M. Kristensen, "NRDC Nuclear Notebook: Russian Nuclear Forces, 2005," *Bulletin of the Atomic Scientists* 61, no. 2 (March/April 2005; available at http://www.thebulletin.org/article_nn.php?art_ofn=ma05norris as of 1 March 2006)

[161] See Bunn and Wier, *Securing the Bomb 2005*, pp. 56-58. The scenario was based on the discussion in Appendix II in Oleg Bukharin, Matthew Bunn, and Kenneth N. Luongo, *Renewing the Partnership: Recommendations for Accelerated Action to Secure Nuclear Material in the Former Soviet Union* (Washington, D.C.: Russian American Nuclear Security Advisory Council, 2000; available at http://bcsia.ksg.harvard.edu/BCSIA_content/documents/mpca2000.pdf as of 10 March 2006), pp. 60-71. An updated version can be found in Oleg Bukharin, *Russia's Nuclear Complex: Surviving the End of the Cold War* (Princeton, N.J.: Program on Science and Global Security, Woodrow Wilson School of Public and International Affairs, Princeton University, May 2004; available at http://www.ransac.org/PDFFrameset.asp?PDF=bukharinminatomsurvivalmay2004.pdf as of 8 March 2006). This would include consolidation of several functions to fewer facilities: HEU and plutonium component manufacture would be centered at Mayak in Ozersk (as has mostly already occurred), Lesnoy would handle warhead assembly and disassembly and some non-nuclear component manufacture, and weapons R&D and other non-nuclear component work would take place at VNIIEF in Sarov, VNIITF in Snezhinsk, and the Institute of Automatics in Moscow. Though the three plutonium production reactors at Zheleznogorsk and Seversk are no longer serving a specific military purpose, the connected workers are part of the 75,000 baseline used to establish the target for this metric, so their eventual shutdown will contribute to progress on this metric.

[162] Personal communication with DOE officials, October 2004.

Sarov and VNIITF at Snezhinsk).[163] By U.S.-Russian agreement, NCI initially focused its work on projects at Sarov, Snezhinsk, and Zheleznogorsk. But the program now plans to phase out most work in Sarov and Snezhinsk in the next year or so: in Sarov, NCI believes the situation has improved enough to shift resources elsewhere, and in Snezhinsk, Russia is refocusing the nuclear facility on its defense mission, reducing the need for defense conversion efforts.[164] NCI now plans to shift its attention to projects in Seversk and Zheleznogorsk, in part to help absorb the excess employees and infrastructure created as another U.S.-sponsored program works to shut down Russia's remaining plutonium production reactors.[165]

NCI has met with moderate success in supporting Russian weapons complex downsizing. The program facilitated the transition of roughly 40% of the Avangard nuclear weapons assembly and disassembly facility from weapons work to open civilian work, though Russia subsequently closed the entire Avangard facility on its own. The remaining employees at Avangard were absorbed into the VNIIEF weapons-design institute also located in the city of Sarov. With roughly 2,700 employees in 2000, Avangard was thought to be the smallest of Russia's four warhead assembly/disassembly facilities.[166] Without U.S. assistance, Russia has also closed its next-smallest nuclear weapons assembly and disassembly facility, at Zarechnyy (though some non-nuclear, weapons work may still be going on there).[167] Only the two largest weapons assembly-disassembly plants—Lesnoy and Trekhgornyy—remain in operation. In addition, Russia appears to have closed one of its two facilities for manufacturing HEU and plutonium components for nuclear weapons (at Seversk). Most of the thousands of employees at Seversk who once worked manufacturing weapons components are reportedly now involved in dismantling these components and blending the HEU down for sale to the United States as commercial reactor fuel,[168] though thousands of workers remain at the plutonium production reactors at Seversk who will be displaced by those reactors' closure.

For FY 2005, GIPP dropped reporting of performance on targets for reducing the Russian nuclear weapons complex. (For FY 2004, GIPP had reported that some 53% of the program's internal "workforce reduction and facility closure" targets in six nuclear cities have been met, though it did not disclose the specific targets.[169])

[163] "Nuclear Cities Initiative" (Washington, D.C.: National Nuclear Security Administration, no date; available at http://www.nnsa.doe.gov/na-20/nci/about_unprec.shtml as of 29 March 2006); U.S. Department of Energy, *FY 2006 Defense Nuclear Nonproliferation Budget Request*, p. 496.

[164] Personal communication with DOE officials, October 2004. See also, Bukharin, *Surviving the End of the Cold War*, p. 21.

[165] U.S. Department of Energy, *FY 2006 Defense Nuclear Nonproliferation Budget Request*, p. 496.

[166] By comparison, Lesnoy (formerly Sverdlovsk-45) is thought to have had some 7,000-10,000 employees in 2000; Trekhgorny (formerly Zlatoust-36) probably had some 3,600; and Zarechnyy (formerly Penza-19) also had some 7,000-10,000 workers. In all of these cases, some of these workers probably also performed some work related to non-physics nuclear weapons component manufacturing. Bukharin, Bunn, and Luongo, *Renewing the Partnership: Recommendations for Accelerated Action to Secure Nuclear Material in the Former Soviet Union*, pp. 38-42, 57-59.

[167] Interview with former First Deputy Minister of Atomic Energy Lev Ryabev, September 2003.

[168] Personal communication from Oleg Bukharin, Princeton University, March 2004.

[169] U.S. Department of Energy, *Performance and Accountability Report: FY 2004*, p. 133. Although the only major facility whose closure the United States has substantially contributed to is Avangard, DOE's statement that 53% of the combined total of the

Without any specific information to the contrary, we maintain our estimate that NCI has helped shut down roughly 7-8% of Russia's remaining excess nuclear weapons complex.[170]

**Rate of progress.** Further dramatic reductions in the nuclear weapons labs at Sarov and Snezhinsk appear unlikely, as NCI has largely shifted its focus to Seversk and Zheleznogorsk. There is no agreement for the United States and Russia to cooperate on closing down more of Russia's nuclear weapons complex. In its FY 2005 Performance and Accountability Report, however, DOE reports that in FY 2005 it sought authority to negotiate a new agreement with the Russian Federation that, in its words, is "designed to permit expanded work at closed nuclear cities in Russia."[171]

## *Improved Stabilizing Metrics for the Future*

The publicly available data for assessing programs in this area are very limited. The total scope of the problem being addressed is not well understood (or even well defined), and there are important gaps in understanding what fraction of that problem has in fact been addressed by the work performed so far. The measures that are readily available provide valuable information on the outputs of the programs, such as the number of institutes engaged or the number of scientists receiving grants. But to the policy-maker or citizen outside the program, such output measures do not answer their essential questions: how much of the problem of potential leakage of nuclear knowledge has been solved, and how could we solve more of it?

Of course, if such measures were easy to come by, we would see them by now. Establishing the full scope of the problem by identifying and quantifying just who did and still does what in one of the most sensitive national security activities—the production of nuclear weapons—in the successor states of the Soviet Union is an extremely challenging task. Given its sensitivity, much of that task can not be carried out in the public realm.

In essence, more data are needed on the denominator of the problem, that is, how many people with what kinds of knowledge and access need new civilian employment. Different kinds of nuclear workers each pose a different type of concern. There is the lead scientist who could design an entire weapon. There is the engineer who might be able to help another state acquire an indigenous nuclear capability, for example by providing knowledge relevant to centrifuge manufacture or machining of nuclear weapons components. There is the production worker who might be able to access HEU or plutonium, and might provide a terrorist group with enough fissile material for a bomb. There is the guard who might provide crucial help in getting others inside a facility. Key questions include: What is the employment distribution of these types of workers in the former Soviet nuclear complex today? How are these categories distributed among defense-related facilities, non-defense enterprises, retirees, or other jobs? How many are now unemployed or underemployed, and how many can be expected to lose their jobs in the near future? How many should be expected to retire (and how many to die) over the next several years? How many should be expected to

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reduction targets for the six sites have been accomplished suggests that the targets for the other five may be modest.

170 Bunn and Wier, *Securing the Bomb 2005*, pp. 57-58.

171 U.S. Department of Energy, *Performance and Accountability Report: FY 2005*, p. 92.

move into civilian jobs outside the nuclear weapons complex without any programs to help them?

Then, in evaluating program performance, we would want to know how many workers from each of these categories have been redirected into sustainable civilian employment where they no longer have access to nuclear material and where they are not in a desperate economic situation. At the same time, Russian performance in their efforts should also be tracked, to recalibrate as necessary the scope of the problem U.S. and other international programs would need to address. Continuously updated understanding of the evolution of economic conditions, attitudes toward proliferation, security enforcement, and the like for Russian nuclear personnel is also a crucial part of understanding how the problem is evolving over time.

We acknowledge that getting specific answers on all these questions is an ideal that will not be achieved in full. But finding more detailed, more accurate information will only serve to help these programs better articulate and execute their mission. Better data on exactly what these efforts have been able to achieve will also make it easier for these programs to find supporters and fend off critics. At the same time, continued efforts to assess the potential willingness of nuclear scientists and workers to contribute to proliferation activities—through polling, individual interviews, focus groups, and the like—can also help improve understanding of the threat, and of the extent to which these programs are in fact helping to convince these individuals not to sell their knowledge or the material to which they have access.[172]

## Tracking Progress: Monitoring Nuclear Stockpiles and Reductions

Currently, few programs are focused on declarations and monitoring of nuclear weapons and fissile material stockpiles in the United States, Russia, and the other nuclear weapon states, or of nuclear weapon dismantlement, though the Bush administration has proposed some limited transparency measures relating to tactical and strategic nuclear weapons.[173] Nevertheless, we continue to include metrics of the status of monitoring and declarations of nuclear stockpiles because we believe implementation of such transparency measures would serve international security by contributing to steps to ensure that all nuclear stockpiles are secure and accounted for and by laying the foundation for verifiable deep reductions in nuclear arms.[174]

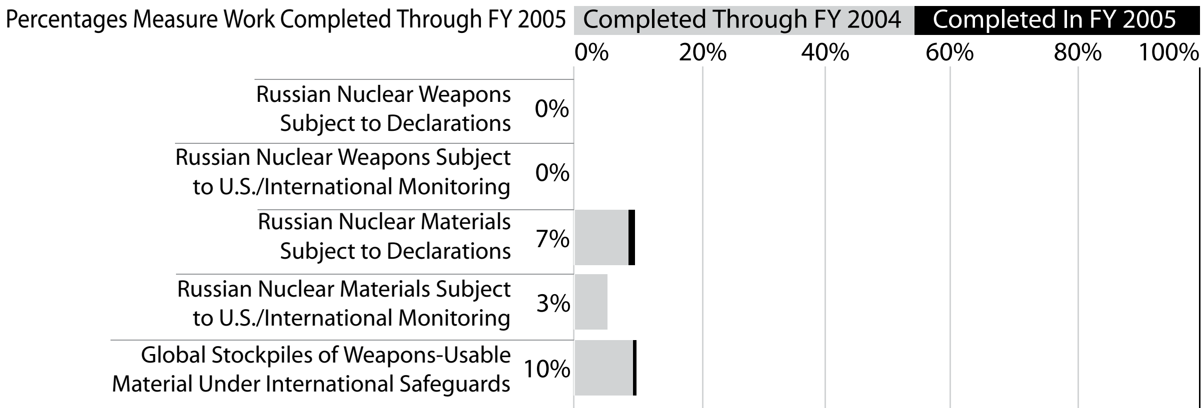
We judge progress in this area with: the fraction of Russia's nuclear warheads and

[172] For an example of such polling and interviews, see Ball and Gerber, "Russian Scientists and Rogue States." Also, Valentin Tikhonov, *Russia's Nuclear and Missile Complex: The Human Factor in Proliferation* (Washington D.C.: Carnegie Endowment for International Peace, 2001; available at http://www.ceip.org/files/projects/npp/resources/humanfactor-flyer.htm as of 9 June 2006).

[173] See, for example, the brief discussion in U.S. Department of State, *FY 2005 Performance and Accountability Report* (Washington, D.C.: U.S. Department of State, 2005; available at http://www.state.gov/documents/organization/58043.pdf as of 16 May 2006), p. 162.

[174] For discussions, see U.S. National Academy of Sciences, Committee on International Security and Arms Control, *Monitoring Nuclear Weapons and Nuclear-Explosive Materials* (Washington, D.C.: National Academy Press, 2005; available at http://books.nap.edu/catalog/11265.html as of 8 April 2006); Bunn, Wier, and Holdren, *Controlling Nuclear Warheads and Materials: A Report Card and Action Plan*, pp. 147-149; Nicholas Zarimpas, ed., *Transparency in Nuclear Warheads and Materials: The Political and Technical Dimensions* (Oxford: Oxford University Press for the Stockholm International Peace Research Institute, 2003).

***Figure 3-5***
***How Much Monitoring Work Have U.S.-Funded Programs Completed?***




materials that have been the subject of detailed declarations; the fraction of those warheads and materials that are subject to actual monitoring; and the fraction of global stockpiles of weapons-usable materials that are under international safeguards.

### *Monitoring Metric 1: Russian Nuclear Weapons and Materials Subject to Declarations*

**Fraction accomplished.** Remarkably, the United States and Russia have never told each other how many nuclear weapons or how many tons of plutonium and HEU they have. Nor has either country ever allowed the other to verify the dismantlement of a single nuclear warhead. Therefore the fraction of nuclear warheads subject to detailed declarations is zero.

In the case of nuclear materials, every year another 30 tons of HEU is blended down, and becomes subject to declarations (and monitoring, as described below) as part of that process. (Blending that material down, of course, also shrinks the total quantity of material remaining.) In addition, under the terms of the Plutonium Production Reactor Agreement (PPRA), Russia makes declarations of the amount of plutonium produced in its plutonium production reactors since January 1, 1997, all of which is stored in oxide form at Seversk and Zheleznogorsk.[175] While these declarations are kept confidential, at an estimated rate of 1.2 tons per year, this should now amount to some 8-12 tons of plutonium. Russia also makes public declarations every year on its stockpiles of separated civilian plutonium. As of the end of 2004 (the most recent year for which declarations are yet available), Russia's civil separated plutonium declaration included 41.2 tons of material.[176] Hence, as shown in Figure 3-5, the total amount of nuclear material subject to declarations is in the range of 80 tons, almost 7% of the

[175] *Agreement between the Government of the United States of America and the Government of the Russian Federation Concerning Cooperation Regarding Plutonium Production Reactors* (Washington, D.C.: U.S. Department of Energy, 1997; available at http://www.nnsa.doe.gov/na-20/docs/PPRA_new.pdf as of 16 May 2006).

[176] International Atomic Energy Agency, *Communication Received from the Russian Federation Concerning Its Policies Regarding the Management of Plutonium*, INFCIRC/549/Add.9/7 (IAEA, 2005; available at http://www.iaea.org/Publications/Documents/Infcircs/2005/infcirc549a9-7.pdf as of 30 March 2006). As the annual increases in Russia's reports have been increasing by amounts ranging from 1 ton to 2.8 tons in recent years, by the end of 2005, Russia's total quantity of civilian separated plutonium probably amounted to 41-43 tons.

estimated 1,215 tons of weapons-usable nuclear material in Russia as of the end of 2005, or some 13% of the 600 tons of that total stockpile that is believed to be outside of nuclear weapons themselves.[177]

**Rate of progress**. The only increases in the amount of material subject to declarations in the past year have been the additional plutonium produced in Russia in the past year—roughly 1.2 tons in the old plutonium production reactors, and roughly 1.5 tons of civilian plutonium separated at Mayak. In the future, if transparency measures are eventually agreed for the Mayak Fissile Material Storage Facility and fissile material begins to be loaded there, that material may effectively come under declarations, as the United States may, depending on the specific measures agreed to in the final transparency arrangements, be informed of roughly how much material is present in the facility. Thus, over the next few years, some 25 tons of plutonium should be added to the amounts just described—or more, if the United States and Russia agree on policy changes that would allow more material to be stored there.[178] Beyond that, progress in bringing additional weapons or materials under declarations is minimal.

### *Monitoring Metric 2: Russian Nuclear Weapons and Materials Subject to U.S. or International Monitoring*

**Fraction accomplished.** As with declarations, no warheads are currently subject to monitoring. In the case of nuclear materials, the 30 tons of HEU being downblended each year are subject to limited monitoring during that process (and are removed from the total stockpile). Limited monitoring of the plutonium produced in Russia's plutonium production reactors since 1994 (amounting to some 8-12 tons of plutonium) is now occurring, although as of early 2006, U.S. monitors had still not been allowed to take measurements on the canisters containing this material (as provided for under the plutonium reactor agree-

[177] The 1,215-ton figure is an update from the end-2003 figures presented in Albright and Kramer, *Global Stocks of Nuclear Explosive Materials*. They estimate 145 tons of military plutonium; 38 tons of civilian separated plutonium reported by Russia; 1,070 tons of remaining military HEU; and 22 tons of civilian HEU, for a total of 1,275 tons of separated plutonium and HEU. These estimates all have substantial uncertainties: the total is uncertain to plus or minus hundreds of tons. In the two years between the end of 2003 and the end of 2005, an additional 60 tons of HEU was blended down in the U.S.-Russian HEU purchase agreement; roughly 2.4 tons of plutonium was produced in the plutonium production reactors; roughly 3 tons of plutonium was separated at Mayak (assuming the 2005 rate was comparable to the 2004 rate declared by Russia); and perhaps 4 tons of HEU was either destroyed as part of the Material Consolidation and Conversion program or consumed in reactors, reducing the total to something in the range of 1,215 tons. In our previous reports, we had incorrectly failed to include the plutonium from the plutonium production reactors in the total subject to declarations.

[178] Currently, the United States takes the view that only weapons-grade plutonium or weapons-grade HEU which will never be returned to weapons can be stored in this facility. Russia takes the view that the HEU in this category is already being blended for sale to the United States under the HEU purchase agreement and does not require storage at Mayak, and the only plutonium it is willing to place in this category is the 34 tons covered by the 2000 U.S.-Russian Plutonium Management and Disposition Agreement, of which 9 tons is material produced in the plutonium production reactors in recent years and stored there, leaving only 25 tons of plutonium eligible for placement in the Mayak storage facility—enough to fill one-quarter of the facility. The United States is considering approaches that would allow additional material to be stored at Mayak, such as having one portion of the facility limited to excess plutonium that would never be returned to weapons and would be subject to monitoring, and another portion where Russia could store a portion of the plutonium still reserved for support of its military stockpile. See Matthew Bunn, "Mayak Fissile Material Storage Facility," in *Nuclear Threat Initiative Research Library: Controlling Nuclear Warheads and Materials* (2004; available at http://www.nti.org/e_research/cnwm/securing/mayak.asp as of 14 February 2006).

ment), because of disagreements over the specifics of the measurements to be taken and the equipment to be used.[179] Together, the plutonium and HEU being monitored represents some 3% of Russia's total nuclear material stockpile, or nearly 7% of the estimated 600 tons outside of weapons.

**Rate of progress.** As noted earlier, there are no current plans for monitoring of warhead stockpiles. For material stockpiles, the rate of increase in the amounts of materials subject to monitoring has been painfully slow. As just noted, 25 tons or more of plutonium is slated to be loaded into the Mayak Fissile Material Storage Facility over the next few years, and if all goes well, this will be subject to some form of transparency. Over the longer term, monitoring of plutonium being burned as fuel in the plutonium disposition effort would begin, but all of this material would be either from the plutonium stored at Mayak (which, if transparency arrangements are agreed, will already be subject to monitoring), or plutonium from the stocks at Russia's plutonium production reactors (also already subject to monitoring).

### *Monitoring Metric 3: Global Stockpiles of Weapons-Usable Material Under International Safeguards*

**Fraction accomplished.** All non-nuclear-weapon states which are party to the Nonproliferation Treaty (NPT)—which is to say, all but nine states in the world—are required to place all their nuclear stockpiles under IAEA safeguards. In addition to their role in confirming that states have not diverted nuclear material under safeguards for military purposes, safeguards provide an important measure of international transparency and confidence, and impose multilateral discipline on the quality of material accounting. The IAEA does not safeguard military nuclear material, and nuclear weapon states are not required to place their nuclear materials under IAEA safeguards (though a small amount of material in these states is under safeguards under voluntary offer agreements, and French and British civilian material is under Euratom safeguards, integrated with the IAEA).

Hence, as of the end of 2004, only 89 tons of separated plutonium outside of reactor cores (of which over 74 tons were in Britain and 2 tons in the United States) and 32 tons of HEU, was under IAEA safeguards.[180] Britain and France, however, declared that a total of 181 tons of separated civilian plutonium was on their soil as of the end of 2004.[181] While only a portion of this material (largely in Britain) is subject to IAEA safeguards, all of it is subject to EURATOM safeguards, so the total quantity of plutonium subject to some form of international safeguards at the end of 2004 was in the range of 195

[179] Defense Threat Reduction Agency, "Plutonium Production Reactor Agreement" (Fort Belvoir, Vir.: DTRA, 2006; available at http://www.dtra.mil/press_resources/fact_sheets/display.cfm?fs=ppra as of 9 June 2006).

[180] See Table A18 in International Atomic Energy Agency, *Annual Report 2004* (Vienna: IAEA, 2005; available at http://www.iaea.org/Publications/Reports/Anrep2004/anrep2004_full.pdf as of 13 February 2006). Supplemented by personal communication from IAEA safeguards officials, June 2006.

[181] This includes 102.7 tons for Britain and 78.5 tons for France. See International Atomic Energy Agency, *Communication Received from the United Kingdom of Great Britain and Northern Ireland Concerning Its Policies Regarding the Management of Plutonium*, INFCIRC/549/Add. 8/8 (Vienna: IAEA, 2006; available at http://www.iaea.org/Publications/Documents/Infcircs/2006/infcirc549a8-8.pdf as of 16 May 2006); International Atomic Energy Agency, *Communication Received from France Concerning Its Policies Regarding the Management of Plutonium*, INFCIRC/549/Add. 5/9 (Vienna: IAEA, 2005; available at http://www.iaea.org/Publications/Documents/Infcircs/2005/infcirc549a5-9.pdf as of 16 May 2006).

tons.[182] Similarly, Britain and France have declared that as of the end of 2004, just under 8 tons of civil HEU was on their soil.[183] Again, all of this material is under EURATOM safeguards, though none of it appears to be included in the total under IAEA safeguards, so the total quantity of HEU subject to some form of international safeguards at the end of 2004 was in the range of 40 tons.

The separated plutonium under some form of international safeguards represented nearly 40% of the global stockpile of separated plutonium at that time, but the HEU under safeguards represented only about 2% of the global stock of that material (reflecting the much smaller scale of civilian use of HEU). All told, it appears that approximately 10% of the global stockpile of weapons-usable nuclear material was under some form of international safeguards as of the end of 2004.

**Rate of progress.** There are currently no major moves underway to place additional plutonium and HEU under international safeguards. The only additional separated plutonium or HEU placed under safeguards in most years is the additional amount of separated plutonium produced in those countries where these operations are under safeguards. Ultimately, all civilian separated plutonium and HEU worldwide, and all military plutonium and HEU no longer needed for military purposes, should be placed under safeguards.

### *Improved Monitoring Metrics for the Future*

The U.S. government should assess what declarations, monitoring, and other transparency measures would give it confidence that nuclear weapons and weapons-usable nuclear materials around the world were safe and secure, and being managed in compliance with international agreements. It should then track what fraction of the measures needed to achieve that confidence have yet been put in place.

## Tracking Progress: Ending Production

World stocks of nuclear weapons, separated plutonium, and HEU are far larger than needed for any current or future military or civilian purposes. Adding further to these stockpiles will increase the cost and complexity of ensuring they are effectively guarded and controlled. Hence, ending production of these materials for both military and civilian purposes is an important objective.

As discussed in the previous chapter, there has been very little progress in stopping production of bomb material in potential new nuclear weapon states or in stopping production of military and civilian weapons-usable nuclear material worldwide, though the last year did see some forward movement in the effort to build alternative power sources to allow Russia's plutonium production reactors to shut down.

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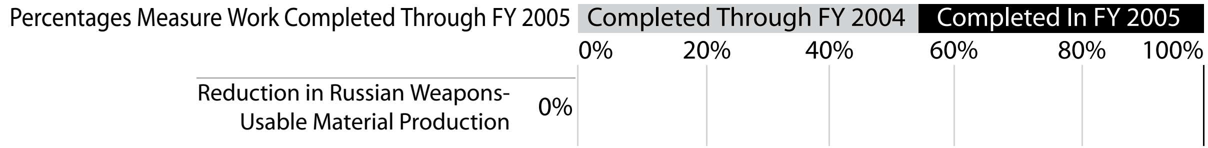
[182] This includes 12.3 tons in states with comprehensive IAEA safeguards; 0.1 tons in states with safeguards limited to particular facilities under Information Circular (INFCIRC) 66 safeguards (this is material in India); 2 tons of plutonium in the United States declared excess to U.S. military needs; and the 181 tons of separated civil plutonium in Britain and France.

[183] This includes roughly 6.4 tons in France and 1.5 tons in the United Kingdom. See International Atomic Energy Agency, *Communication Received from the United Kingdom of Great Britain and Northern Ireland Concerning Its Policies Regarding the Management of Plutonium*; International Atomic Energy Agency, *Communication Received from France Concerning Its Policies Regarding the Management of Plutonium*.

**Figure 3-6**
**How Much Ending Production Work Have U.S.-Funded Programs Completed?**




### Ending Production Metric 1: Reduction in Russian Weapons-Usable Material Production

**Fraction accomplished.** The ultimate metric here is very simple: the reduction in the rate of weapons-usable material production resulting from U.S. sponsored programs. So far, this is zero, as U.S.-funded programs have not affected this production rate—and it will remain zero until the first of the three remaining plutonium production reactors actually shuts down (Figure 3-6 reflects this outcome-oriented assessment).

The picture is more promising if judged by the fraction of all the work that needs to be done to shut these reactors down that has been completed. In 2005, major construction got underway on the refurbishment of a coal plant in Seversk; DOE estimates that by the end of FY 2005, that project was more than 25% complete (though this fell more than 6% short of the target for the year).[184] DOE is requesting a sharp increase in funding to accelerate the Zheleznogorsk project in FY 2007 (from $47 million in FY 2006 to $120 million in FY 2007), but to date the project is only in its earliest stages; just under 5% of the Zheleznogorsk project was completed by the end of FY 2005.[185]

**Rate of progress.** As just noted, DOE estimates that more than 25% of the work needed to shut down the Seversk reactors was done by the end of FY 2005, essentially doubling the percentage completed by the end of FY 2004. DOE expects to complete another 30% of the work during FY 2006, bringing the total to 55%, and to complete the project by December 2008.[186] DOE expects to complete less than 5% of the Zheleznogorsk effort in FY 2006, but hopes that the project will then accelerate during FY 2007–2009. Completion of the Zheleznogorsk efforts is slated for December 2010.[187]

### Improved Ending Production Metrics for the Future

The U.S. government should develop measures to assess progress in ending (or preventing) production of nuclear material in potential or new nuclear weapon states such as North Korea and Iran. It should also estimate global production of nuclear materials for weapons each year and progress in bringing that production to an end. Finally, it should develop estimates of *total*—that is, both military and civilian—worldwide production of weapons-usable nuclear material each year, and of progress in reducing (and ultimately ending) that production.

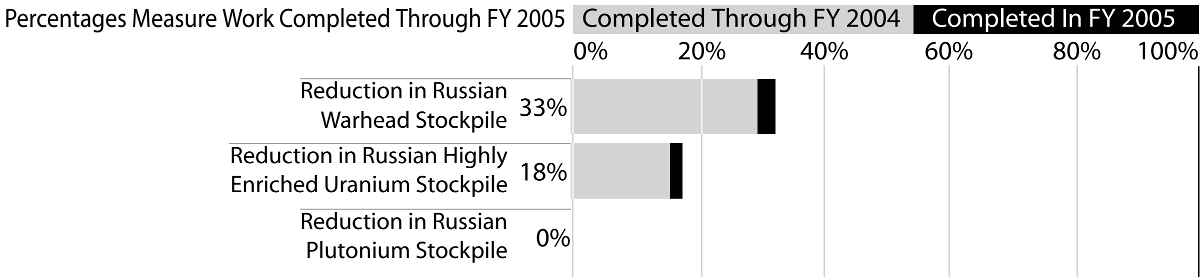
[184] U.S. Department of Energy, *FY 2007 Defense Nuclear Nonproliferation Budget Request*, pp. 525-526.

[185] U.S. Department of Energy, *FY 2007 Defense Nuclear Nonproliferation Budget Request*, pp. 525-529.

[186] U.S. Department of Energy, *FY 2007 Defense Nuclear Nonproliferation Budget Request*, p. 525.

[187] U.S. Department of Energy, *FY 2007 Defense Nuclear Nonproliferation Budget Request*, p. 525.

***Figure 3-7***
***How Much Reducing Stockpiles Work Have U.S.-Funded Programs Completed?***




## Tracking Progress: Reducing Nuclear Stockpiles

Ultimately, the only way to guarantee that any particular nuclear weapon or cache of weapon-usable nuclear material will not be stolen is to destroy it. Reductions in the total size of these stockpiles are also an important long-term foundation for deep and difficult-to-reverse reductions in nuclear arms.

Between them, the United States, Russia, France, and Britain have dismantled thousands of nuclear weapons since the end of the Cold War. Non-government estimates suggest that as of the end of 2005 there were still some 27,000 nuclear weapons in the world, compared to well over 40,000 when the Soviet Union collapsed.[188] To date, however, there are no arms control agreements that call for destroying nuclear warheads themselves (as opposed to simply taking them off of delivery systems)—though the United States and Russia made unilateral pledges to destroy large portions of their tactical nuclear weapons in 1991-1992. Moreover, although DOD's Cooperative Threat Reduction (CTR) program, commonly known as Nunn-Lugar, is often thought of as a weapons dismantlement effort, no U.S. money has ever gone to finance the actual dismantlement of Russian nuclear warheads (as that would require verification that the warheads were in fact being dismantled, which the two sides have never agreed to do). CTR does pay for shipments of warheads to storage and dismantlement sites, and it routinely pays for the dismantlement of nuclear missiles, bombers, and submarines; but it does not pay for dismantlement of the warheads themselves.

With respect to reductions in nuclear materials, the key agreements in place are the U.S.-Russian HEU Purchase Agreement, which commits Russia to eliminating 500 tons of weapons-grade HEU by blending it to LEU for sale to the United States, and the Plutonium Management and Disposition Agreement (PMDA) of 2000, which commits both Russia and the United States to carry out disposition of 34 tons of weapons-grade plutonium (possibly mixed with up to an additional four tons of reactor-grade plutonium).[189]

[188] For current estimates, see, for example, Hans M. Kristensen, "Status of World Nuclear Forces" (Washington, D.C.: Nukestrat.com, 2006; available at http://www.nukestrat.com/nukestatus.htm as of 21 June 2006). For an estimate of the global stockpile at the time of the Soviet collapse in 1991, see, for example, Robert S. Norris and Hans M. Kristensen, "NRDC Nuclear Notebook: Global Nuclear Stockpiles, 2002," *Bulletin of the Atomic Scientists* (November/December 2002; available at http://www.thebulletin.org/article_nn.php?art_ofn=nd02norris as of 17 May 2006).

[189] For more, see Matthew Bunn, "HEU Purchase Agreement," in *Nuclear Threat Initiative Research Library: Controlling Nuclear Warheads and Materials* (2003; available at http://www.nti.org/e_research/

Implementation of the HEU Purchase Agreement (and of unilateral U.S. programs to reduce its own excess HEU stockpile) continues, but disposition of both U.S. and Russian excess plutonium has been delayed for years. In addition to destroying weapons-usable HEU, the HEU Purchase Agreement also gives Russia a financial incentive to continue large-scale weapons dismantlement, in order to provide the HEU for blending and sale to the United States.

Our metrics in this area are very simple—the fractions of the relevant stockpiles that have been reduced. Because U.S.-funded cooperative programs in these areas have focused only on Russia, our metrics focus only on the reductions achieved in the Russian stockpiles, rather than those achieved in the global stockpiles.

### *Reducing Metric 1: Reduction in Russian Warhead Stockpile*

**Fraction accomplished.** As noted above, there are no current U.S.-funded programs directly focused on reducing the Russian stockpile of nuclear warheads. Nevertheless, Russia has dismantled thousands of nuclear warheads since the collapse of the former Soviet Union, and some U.S. programs provide indirect assistance in or incentives for that process.

Under DOD's nuclear warhead transportation program, by the end of FY 2005 the United States had paid for 284 nuclear warhead shipments, typically carrying some 20-30 warheads each, either to central storage facilities or to dismantlement facilities.[190] This represents a shipment of some 5,000-9,000 warheads. No public breakdown is available of how many of these shipments were to storage sites and how many were for dismantlement; if half of these shipments led to the dismantlement of shipped warheads, this effort would have contributed to the dismantlement of some 2,500-4,500 nuclear warheads.

The U.S.-Russian HEU Purchase Agreement has also provided a financial incentive to dismantle warheads, by arranging for the commercial sale of uranium blended from the HEU warheads contain. By the end of 2005, over 260 tons of HEU had been blended down under this agreement; if we assume that, on average, Russian warheads contain 25 kilograms of HEU, this is the equivalent of well over 10,000 nuclear warheads.[191] Presumably a large fraction of the warheads transported to dismantlement facilities with U.S. assistance were the same as warheads dismantled to provide HEU for the HEU Purchase Agreement, and hence these figures should not be added together. What is unknown, however, is (a) how much of the HEU blended down to date was from warheads dismantled even before the HEU Purchase Agreement was negotiated (dismantlement of which the agreement therefore could not take credit for), and (b) how many warheads Russia had when the agreement began. By some public estimates, Russia had some

cnwm/reducing/heudeal.asp as of 29 March 2006). On plutonium disposition, see U.S. Department of Energy, *Agreement between the Government of the United States of America and the Government of the Russian Federation Concerning the Management and Disposition of Plutonium Designated as No Longer Required for Defense Purposes and Related Cooperation* (Washington, D.C.: DOE, 2000; available at http://www.nnsa.doe.gov/na-20/docs/2000_Agreement.pdf as of 30 March 2006).

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

[191] USEC, "Chronology: U.S.-Russian Megatons to Megawatts Program: Recycling Nuclear Warheads into Electricity (as of January 3, 2006)" (Bethesda, Md.: USEC, 2006; available at http://www.usec.com/v2001_02/HTML/Megatons_chronology.asp as of 31 March 2006).

32,000 warheads in 1993, when the HEU Purchase Agreement began, and has since reduced this figure to some 16,000.[192] If all of the HEU blended to date came from warheads dismantled in part as a result of this HEU deal (a generous assumption), then it could be argued that U.S. programs have contributed to the dismantlement of roughly 33% of the total stockpile of nuclear warheads that Russia had when the agreement began, as noted in Figure 3-7.

**Rate of progress**. The nuclear warhead transportation program resumed in June 2005, after the United States and Russia resolved a dispute that had brought the program to a halt in November 2004. The dispute centered on whether Russia might be using some U.S.-funded shipments for operations of its nuclear stockpile (rather than for storage and dismantlement). It was resolved with an amended transparency agreement.[193] DOD financed 25 such shipments in FY 2005 after the program resumed, and plans through FY 2012 to finance an average of roughly 50 shipments per year, transporting some 1,000-1,500 warheads per year.[194]

Today, some 30 tons of HEU is being blended down every year under the HEU Purchase Agreement, representing the equivalent of some 1,200 warheads per year, roughly an additional 4% each year of the warheads Russia had when the HEU Purchase Agreement began. The HEU Purchase Agreement is currently scheduled to end in 2013, and no decisions have yet been announced concerning what will happen to the large remaining Russian stockpile of HEU that will exist at that time, much of which is far beyond Russia's plausible military needs.

### *Reducing Metric 2: Reduction in Russian Highly Enriched Uranium Stockpile*

**Fraction accomplished.** As just noted, by the end of 2005, 262 metric tons of HEU had been destroyed (by blending it to low enriched uranium reactor fuel) as part of the U.S.-Russian HEU Purchase Agreement. In addition, by the end of FY 2005, some 7.1 tons of HEU had been destroyed as part of the Material Consolidation and Conversion (MCC) effort in DOE's MPC&A program.[195] This represents some 21% of the over 1,200 tons of weapons-grade HEU equivalent Russia was believed to possess when the HEU deal began.[196]

**Rate of progress.** As already described, an additional 30 tons of HEU is currently being destroyed each year, representing roughly an additional 2% of the original Russian HEU stockpile. The program is

[192] Robert S. Norris and Hans M. Kristensen, "NRDC Nuclear Notebook: Russian Nuclear Forces, 2005."

[193] U.S. Department of Defense, *FY 2007 CTR Annual Report*, p. 30.

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

[195] U.S. Department of Energy, *FY 2006 Defense Nuclear Nonproliferation Budget Request*, p. 485.

[196] David Albright has recently estimated that Russia had 1,070 tons of military HEU as of the end of 2003, and 15-30 tons of civil HEU. (These are somewhat inconsistently expressed, as the 1,070 figure is also the centerpoint of an estimate with a wide uncertainty range.) These figures would have been somewhat more than 200 tons higher when the HEU Purchase Agreement began, before HEU began to be destroyed in that effort. See Albright and Kramer, eds., *Global Fissile Material Inventories*. For a discussion of a range of previous unclassified estimates, and of the various uses that are drawing down Russia's HEU stockpile over time, see Matthew Bunn, "Unclassified Estimates of Russia's Plutonium and HEU Stockpiles—and World Civil Separated Plutonium Stockpiles: A Summary and Update, Rev. 1" (Cambridge, Mass.: unpublished, 2003).

currently scheduled to end in 2013, after 500 tons—some 40% of the original stockpile—has been blended. In addition, DOE plans to blend down 1.5 tons of HEU in FY 2006 and 1.1 tons in FY 2007 in the MCC effort (scaled back from previous projections of two tons per year).[197] Russia is also consuming some of its HEU stockpile as fuel for naval, icebreaker, research, and plutonium production reactors, and is using some for commercial production of LEU fuel from European reprocessed uranium.[198] To address a larger fraction of the stockpile more quickly, the blend-down of HEU should be substantially accelerated, and expanded well beyond the 500 tons initially agreed.[199]

### *Reducing Metric 3: Reduction in Russian Plutonium Stockpile*

**Fraction accomplished.** Years of effort and hundreds of millions of dollars of investment have been focused on laying the groundwork for disposition of excess weapons plutonium. Russia has almost completed site preparation work where the plutonium fuel fabrication facility is to be built. DOE, meanwhile, has been working closely with Russian regulators to lay the groundwork for licensing fabrication of MOX fuel in Russia and its use in Russian reactors. Early preparations to use MOX fuel in Russia's VVER-1000 reactors have also been underway. But Russia has recently reiterated its reluctance to use its excess plutonium as MOX fuel in light-water reactors, arguing that it is more efficient to use it in fast-neutron reactors, both the BN-600 that already exists, and the modestly larger BN-800 Russia hopes to build. This shift has once again thrown the program into some disarray, with the United States and Russia again discussing what technological approaches to plutonium disposition should be pursued. In any case, the program is not yet at the point where any substantial amounts of excess weapons plutonium have been used as reactor fuel or otherwise transformed into forms unsuitable for weapons use. Indeed, large-scale construction of the MOX for fabricating light-water-reactor fuel has not yet begun, and now may never begin. Hence, the fraction accomplished to date in actually reducing the stockpile of Russian weapons plutonium is zero.

**Rate of progress.** To date, the annual rate of progress in reducing excess plutonium stockpiles is also zero, if measured by actual plutonium eliminated. As noted above, while some obstacles were overcome in the past year, others remain. Actual construction of the needed MOX plant in Russia did not begin in FY 2005, and DOE does not include actual plant construction among the expected activities in Russia in FY 2006.[200] Even if the two sides returned to the idea of building a MOX plant to manufacture fuel for existing reactors, and all other current issues were resolved quickly, it would probably take some five years after construction got under way to build the MOX plant and other needed facilities. Hence, it is unlikely that disposition of substantial amounts of plutonium will begin before

[197] U.S. Department of Energy, *FY 2007 Defense Nuclear Nonproliferation Budget Request*, p. 514. For the earlier projection, see U.S. Department of Energy, *FY 2006 Defense Nuclear Nonproliferation Budget Request*, p. 485.

[198] Bunn, "Unclassified Estimates of Russia's Plutonium and HEU Stockpiles—and World Civil Separated Plutonium Stockpiles."

[199] The Nuclear Threat Initiative (NTI) has sponsored a detailed study by Russian experts (including experts from the facilities doing the work) of the feasibility, schedule, and costs for various approaches to accelerating the blend-down of HEU. A follow-on study to optimize the approaches to reduce total costs is now underway.

[200] Rather, DOE refers to continued work on preparing the site and relevant licensing documents. U.S. Department of Energy, *FY 2007 Defense Nuclear Nonproliferation Budget Request*, p. 534.

2012—though there is some possibility for "early disposition" at a modest rate in the existing BN-600 fast reactor, using fabrication facilities that already exist or can be upgraded. Under the 2000 agreement, Russia and the United States were each to carry out disposition of two tons of plutonium a year—far more than can be done in the BN-600 alone—and then shift up to four tons of plutonium per year thereafter. Even if such rates could be achieved, completing disposition of just the 34 tons of excess weapons plutonium covered by the agreement—a small fraction of Russia's total plutonium stockpile—would take until 2020-2030. Indeed, as Russia's plutonium production reactors continue to produce plutonium, and Russia continues to separate weapons-usable civilian plutonium as well, if these are not stopped in a timely way, a two-ton-per-year disposition program would effectively be running in place—eliminating as much plutonium every year as is produced every year.[201] If production were stopped, but disposition of all 170 tons of Russia's stockpile except the amount needed to sustain a stockpile of 10,000 warheads were included in the program, at four tons a year, completion of the plutonium disposition effort would stretch beyond 2040 (or beyond 2070 at two tons per year).

### *Improved Reducing Metrics for the Future*

The U.S. government should develop an assessment of (a) the total world stockpiles of nuclear weapons; (b) the total world military stockpiles of HEU and separated plutonium, and (c) the total world civilian stockpiles of HEU and separated plutonium. It should then track progress in reducing these total stockpiles.

[201] The plutonium production reactors continue to produce in the range of 1.2 tons of plutonium per year, and Russia's declarations of separated civilian plutonium have increased, on average, by 1.3 tons per year for the past several years. Thus, the total increase in separated plutonium stocks is in the range of 2.0–2.5 tons per year.

## Summary: How Much of the Job is Done?

Figure 3-8 summarizes what fraction of the job has been accomplished, when judged by the metrics described above for each of the six categories of effort. Also shown is the fraction of the job that was accomplished during FY 2005, to give an impression of the current rate of progress when judged by these metrics. There are substantial uncertainties in all of these estimates—even those based on official government data, since those data are themselves uncertain.

Overall, it is clear that while much has been accomplished in these efforts, across a broad range of metrics, an immense amount of work remains. Despite the dedicated efforts of hundreds of experts and officials from the United States, Russia, and other countries and organizations, there remains too much space on this chart—space that represents thousands of warheads that may be insufficiently secure, enough nuclear material for tens of thousands more for which security upgrades have not yet been installed, and thousands of excess nuclear weapons scientists and workers not yet permanently redirected to civilian work. If the world is to win the race to lock down nuclear stockpiles before terrorists and thieves can get to them, urgent steps remain needed to accelerate, expand, and strengthen these critical efforts.

***Figure 3-8***
***Controlling Nuclear Warheads, Material, and Expertise: How Much Work Have U.S.-Funded Programs Completed?***