5. Output Measures: How Much Is Done, And How Fast is the Rest Getting Done?

After more than 10 years of effort in cooperative threat reduction, and a year and a half after the September 11 attacks, two questions must be asked:

- How much of what needs to be done to keep nuclear weapons, materials, and expertise out of the hands of terrorists and hostile states has already been accomplished?

- How fast is what's left to be done being finished?

Our effort to answer these questions is complicated by the fact that no integrated plan for these efforts exists, setting out all the work that needs to be done. In addition, many specific programs have not publicly outlined their objectives and measurable milestones for meeting them against which their progress could be judged.

Below, therefore, we have used the government's own performance measures and data where these are available, and where they are not, we have attempted to develop our own statements of the objectives these programs should be reaching, rough metrics by which progress toward these objectives can be assessed, and estimates of how much of those metrics have been completed. Where estimates were required, we have tried to be generous, to avoid understating the work accomplished in these programs to date.

In this chapter, we provide only simple, top-level measures that are inevitably incomplete (as we discuss in each case); for more detailed and nuanced program-by-program assessments of the progress of and problems facing each of these efforts, see this report's on-line companion.[1] We recommend, in keeping with the Government Performance and Results Act, that each of these programs publish clearly defined descriptions of the objectives they are seeking (including the final end state at which their program could be considered "finished"), and clearly defined approaches that can be used to assess how much progress is being made in meeting these objectives.

From the review of dozens of threat reduction programs presented in the on-line companion to this report, there is a clear and impressive record of accomplishment. While cooperation in these sensitive areas has been difficult, and there have been plenty of problems and missteps along the way, the reality is that as a result of cooperative programs already underway hundreds of tons of nuclear material and thousands of nuclear weapons are demonstrably more secure; enough nuclear material for thousands of nuclear weapons has been permanently destroyed; and thousands of underemployed nuclear weapons experts have received support for redirecting their talents to civilian work. These efforts have represented an extremely cost-effective investment in the security of the United States, Russia, and the world. But that review also makes clear that much more remains to be done – and that the pace at which it is now being done simply does not match the urgency of the threat.

Assessing Three Types of Threat Reduction Programs

Ideally, one would like to answer the question: "how much have we reduced the risk of a terrorist setting off a bomb in a U.S. city?" Unfortunately, progress toward that goal cannot be measured directly. There is not even any way to accurately measure how much various programs have increased the probability of blocking each of the steps on the terrorist pathway to the bomb. Efforts to maintain nuclear deterrence during the Cold War

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1 *Controlling Nuclear Warheads and Materials* (available at http://www.nti.org/cnwm as of March 12, 2003).

faced the same problem: an absolutely critical objective with no clear and direct means for measuring how much progress was being made toward achieving it. In both cases, the best that can be done is to develop theories of what steps would lead to accomplishing the objective – providing capable and survivable nuclear forces in one case, securing and accounting for nuclear stockpiles and the other steps to block the terrorist pathway to the bomb outlined above in the other – and then attempt to develop reasonable measures of the degree to which these steps are being accomplished. In the case of threat reduction efforts, the job of measuring progress is made particularly difficult by the wide range of different purposes being pursued, and the intangible nature of many of the most important elements of some programs.

For the purposes of developing measures of progress, the many cooperative threat reduction programs fall into three principal categories, based on what they are seeking to accomplish.

Dismantling and destroying excess arms and facilities. Programs involved in eliminating ballistic missiles, destroying chemical weapon stockpiles, and dismantling weapons production facilities typically have readily quantifiable metrics – the number of relevant items destroyed.[2] A more informative figure is the *fraction of the total* destroyed, making it possible to judge whether the number destroyed represents just scratching the surface, nearly finishing the job, or something in between. If data is available, a useful complementary performance metric is one based on cost-effectiveness – for example, weapons dismantled per million dollars spent. This makes it possible to compare the efficiency of different programs performing similar functions, or to judge how much more one is paying to move from one approach (e.g., securing nuclear materials in place) to another (e.g., destroying those nuclear materials permanently).

Even where readily measurable metrics are available, they should be used with caution, as they can often be misleading. Even in the private sector, with the discipline of the market, one cannot simply look at profits each quarter as the only measure of performance of a business unit: during one period that unit may make minimal profit because it is investing in order to achieve greater profits in the future. Hence a "balanced scorecard" reflecting a variety of measures of how units are performing with respect to the overall goals of the organization is required.[3] Much the same is true in threat reduction: spending a year investing to double the capacity of a dismantlement facility, for example, would show up in an assessment based strictly on how many items were dismantled each year as a year in which nothing was accomplished. Plutonium disposition is an extreme case, in which the entire nine-year program to date has been focused on investing to prepare for beginning to reduce excess plutonium stockpiles in the future. One can debate whether this preparation should have been accomplished more quickly, but one cannot judge the program to be a failure simply because no substantial amount of weapons plutonium has yet been eliminated.

Reemploying excess scientists and workers. Here, too, intuitively a simple metric – the number of jobs provided by projects supported by a U.S. program, or the fraction of the target population provided with jobs in this way – seems called for. Here again, however, such a metric can be misleading. The reality is that in a market economy, as Russia is now becoming, nuclear weapons scientists and workers will find jobs wherever seems to make the most sense to them, and this will often be in firms or organizations *not* receiving direct financial support from U.S. programs. But those other jobs may have come into existence because of improvements in the business and investment climate generated in part with help from U.S. programs. Measuring how much the business climate

[2] The Defense Department, in particular, makes constant use of this metric. See Defense Threat Reduction Agency, "Cooperative Threat Reduction Scorecard," November 22, 2002 (available at http://www.dtra.mil/ctr/ctr_score.html as of January 21, 2003).

[3] There is a vast literature on performance assessment and its use to improve management in both the public and private sectors, which we do not propose to review here. See, as a start, the website of the Balanced Scorecard Institute (available at http://www.balancedscorecard.org as of January 21, 2003).

of an area has improved, and how much of that improvement should be attributed to U.S. programs as opposed to other causes, is extraordinarily difficult. Reasonable metrics for assessing this kind of effect have not yet been developed.

Permanently improving the performance of certain government functions. Many threat reduction programs are not focused on dismantling a certain number of missiles or providing a certain number of jobs, but on changing how a recipient government does its business – for example, improving implementation of export controls, strengthening security for nuclear material, or bolstering efforts to interdict nuclear smuggling at national borders. In each of these cases, one can measure the number of sites with particular types of equipment installed, or personnel provided with particular types of training, but these measures are at best incomplete: if the people using this equipment or provided this training are not motivated to carry out the mission properly, it still will not get done even with the best equipment and training in the world.[4] Indeed, experience in other areas of international assistance suggests that programs that focus *only* on providing equipment and training to accomplish a specific technical mission – from tax collection in Bolivia to health care delivery in Botswana – usually have little long-term benefit. The program helps for a while, and then the trainees move on to other jobs, the equipment breaks or wears out, and the system is back to where it started. Only if the programs focus on modifying the entire system in which the function is performed (from the power and budgets of the agencies doing the work, to the regulations specifying what work should be done, to the way the people doing the work are recruited, hired, trained, paid, and promoted) do such assistance programs typically have long-term benefits.[5] Assessing how well programs are doing in the complex job of shifting the way thousands of people in a foreign country do their jobs day to day, and how much of this will last after the assistance program comes to an end, is extraordinarily difficult.[6] Much of the future of threat reduction is in these areas, and many of the most important factors for ensuring U.S. and world security in these areas are difficult-to-measure intangibles.[7]

Accounting for a dynamic picture. Metrics often focus on how much of a task of fixed size has been accomplished – what fraction of the total number of weapons has been dismantled, for example. This is the approach taken in the discussion below, as well. The reality, however, is that for many of these programs, the size of the task is itself changing over time – in part as the result of successes or failures in other U.S. programs. As warheads are dismantled, for example, the number of warheads to be secured shrinks (and the number of sites where they are located may shrink), but the

[4] For a useful discussion of the critical importance of how well individual people perform their roles to maintaining good security for nuclear material, see Igor Khripunov and James Holmes, eds., *The Human Factor and Security Culture: Challenges to Safeguarding Fissile Materials in Russia* (Athens, Georgia: Center for International Trade and Security, University of Georgia, November 2002; available at http://www.uga.edu/cits/publications/Humanfactor.pdf as of February 23, 2003).

[5] See, for example, Merilee S. Grindle, ed., *Getting Good Government: Capacity Building in the Public Sectors of Developing Countries* (Cambridge, Mass.: Harvard Institute for International Development, 1997).

[6] The Materials Protection, Control, and Accounting (MPC&A) program, to its credit, is one of the only threat reduction programs that has made a serious attempt to draft a set of performance metrics that reflect the full complexities of meeting its overall mission. See Department of Energy (DOE), National Nuclear Security Administration, Materials Protection, Control and Accounting Program, *MPC&A Program Strategic Plan* (Washington, D.C.: DOE, July 2001; available at http://www.nti.org/db/nisprofs/russia/fulltext/doe_mpca/doe2001/mpca2001.pdf as of February 5, 2003). Since then, however, it has continued to use only the simplest measures (such as the number of pieces of equipment provided, the number of people trained, and the fraction of material subject to particular types of upgrades) in its public statements assessing progress; it does not appear that much internal use is made of the more complex metrics outlined in the strategic plan either. (Interviews.)

[7] See discussion in *Reshaping U.S.-Russian Threat Reduction: New Approaches for the Second Decade* (Washington, D.C.: Russian American Nuclear Security Advisory Council and Carnegie Endowment for International Peace, November 2002; available at http://www.ceip.org/files/Publications/ransac_report.asp?from=pubdate as of February 5, 2003).

amount of nuclear material outside of warheads that needs to be secured expands. The amount of nuclear material to be secured is also expanding as ever more plutonium is produced – but it is decreasing as highly enriched uranium (HEU) is blended down, and the plutonium figures will stop increasing and begin declining if programs to end plutonium production and begin reducing stockpiles of excess weapons plutonium are successful. These shifts in the overall magnitude of the task to be accomplished, often representing synergies among different threat reduction programs, should be considered in preparing an overall integrated plan for these efforts, and assessing when that plan will be completed.[8]

What U.S. programs can take credit for. Another key issue in assessing the progress of these efforts is judging what fraction of the overall problem needs to be addressed by U.S. programs, and how much of whatever progress is being made is the result of these U.S. programs. Thousands of Russian nuclear warheads have been dismantled over the last decade, for example, but U.S. threat reduction programs did not pay for their dismantlement (though as discussed below, the purchase of nuclear fuel blended from the HEU from these weapons provided a financial incentive for their dismantlement).[9] Russian nuclear weapons scientists are now being paid more, and paid on time, but this is the result of the Russian government getting its budgetary house in order, not the result of anything in particular the United States did. In both cases, it is clear the threat is being reduced, but this reduction should only be attributed to U.S. threat reduction programs when a clear causal link can be drawn.

In general, while U.S. threat reduction programs should not claim credit for events they did not cause, nonetheless those events can reduce the overall scale of the problem to be addressed, and this must be taken into account. For example, while Russia plans to reduce the number of nuclear weapons workers by some 35,000 over the next few years (representing nearly half of its nuclear weapons workforce), this does not mean that U.S. programs need to create 35,000 new jobs for excess nuclear weapons workers: thousands of these individuals will retire or die over the next few years, and Russia's own conversion programs have already created thousands of jobs (by Russia's estimates), and are expected to create thousands more. Hence, a U.S. program that succeeded in creating 5,000 jobs for excess nuclear weapons workers might solve a quarter of the overall problem rather than only a seventh of the overall problem.

Keeping these caveats and difficulties in mind, we have developed a set of rough metrics for assessing how much of the job of controlling nuclear warheads, materials, and expertise has been accomplished, and how fast the remaining work is being done. Below, we provide discussions of rough metrics for such an assessment in each of the six categories described above.

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 secured and accounted for, to stringent standards. The best measure of progress, if the data were available, would be one that was performance-based: the fraction of buildings containing warheads or nuclear material that had demonstrated the ability to defend against a particular specified threat.[10] (It is worth noting that the United States itself does

[8] For a useful discussion, with initial illustrative calculations of possible impacts of these synergies on accelerating achievement of some threat reduction goals, see Leonard S. Spector, "Missing the Forest for the Trees: U.S. Nonproliferation Programs in Russia," *Arms Control Today* (June 2001; available at http://www.armscontrol.org/act/2001_06/specjun01.asp as of February 5, 2003).

[9] Although Nunn-Lugar is often thought of as a weapon dismantlement effort, and it has paid for the dismantlement of many missiles, bombers, and submarines, it has never paid for the dismantlement of a single nuclear warhead – because so far Russia has not been willing to allow inspections to confirm that such warheads are in fact being dismantled. Nunn-Lugar *has* paid for thousands of warheads to be transported to central storage or dismantlement facilities, and the HEU purchase agreement has provided a financial incentive to dismantle warheads and extract their HEU for sale – but it remains unclear how much of the warhead dismantlement that has occurred would have happened in the absence of these efforts.

not do especially well by this metric: U.S. nuclear power plants fail to defend against the threat they are required to be able to cope with roughly half the time in performance tests, and the nuclear weapons facilities of the Department of Energy (DOE) reportedly have a similar record in defending against the larger threat they are required to be able to fend off.[11])

Unfortunately, for nuclear warheads and materials in the former Soviet Union, such data does not yet exist. The best publicly available surrogate, at this point, is the fraction of material that is at sites with two defined levels of security and accounting equipment upgrades installed – "rapid" upgrades and "comprehensive" upgrades. 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.

The fraction of material with particular types of upgrades installed, however, is at best a partial measure, as it ignores the many intangibles in changing the way the job of securing and accounting for nuclear material in these states is done, which are critical to long-term success, but are very difficult to measure. The fraction of material with certain types of equipment installed understates progress in the sense that an enormous amount of work has been done that has national impact – improving regulations, providing training, and developing the infrastructure for supporting modern safeguards and security. At the same time, it overstates progress, in the sense that sites with these kinds of equipment installed may still not be adequately secured if procedures are not followed, equipment is not maintained and improved, and the like – that is, if the overall way that this job is done by the thousands of people involved has not changed for the better, in a way that will last. The Material Protection, Control, and Accounting (MPC&A) program has taken what should be considered a first cut at the complex task of developing appropriate metrics to assess the real state of progress toward achieving sustainable security at these sites for the long term[12] – but much more can and should be done to develop performance measures that adequately reflect the real state of progress, but are simple enough to be useful to policymakers.

Nuclear material in the former Soviet Union: fraction secured. Within the former Soviet Union, as of the end of fiscal year (FY) 2002, some 37% of the vulnerable weapons-usable nuclear material outside of warheads had rapid upgrades

[10] This demonstration could be through realistic performance testing, where exercises are run in which insiders attempt to smuggle something out, or outsiders attempt to break in and steal something (such exercises are required at major nuclear facilities in the United States and some other countries), or through other means of rigorously assessing overall system vulnerabilities.

[11] David N. Orrik, testimony in "A Review of Enhanced Security Requirements at NRC Licensed Facilities," House Committee on Energy and Commerce, Subcommittee on Oversight and Investigations, 107th Congress, 2nd Session, April 11, 2002 (available at http://energycommerce.house.gov/107/hearings/04112002Hearing532/Orrik908.htm as of January 21, 2003). Also, see Project on Government Oversight (POGO), *U.S. Nuclear Weapons Complex: Security at Risk* (Washington, D.C.: Project on Government Oversight, October 2001; available at http://www.pogo.org/nuclear/security/2001report/reporttext.htm as of December 16, 2002).

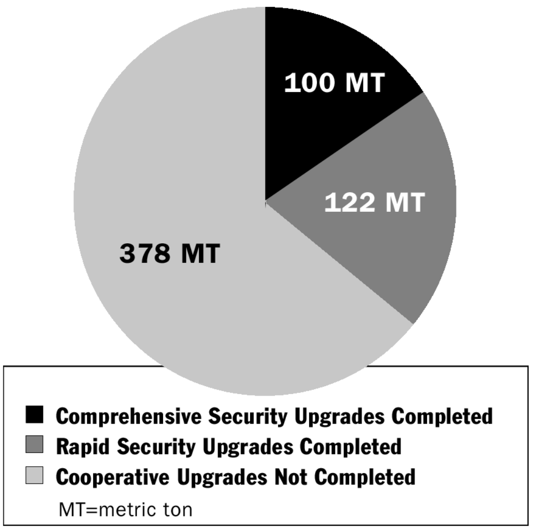
[12] DOE, *MPC&A Program Strategic Plan*, op. cit. For assessing progress toward sustainable security over time, plausible metrics might include the fraction of sites with MPC&A systems that are performing effectively (as judged by performance tests, regulatory inspections, or other forms of expert review); the fraction of sites with long-term plans in place for sustaining their MPC&A systems, and resources budgeted to fulfill those plans; the priority the Russian government was assigning to the task (measured by senior leadership attention and resources assigned to the effort); the presence of stringent MPC&A regulations that were effectively enforced (assessed by expert reviews); and the presence of an effective infrastructure of personnel, equipment, organizations, and incentives to sustain MPC&A (again assessed by expert reviews, given the difficulty of quantification).

of security installed under the DOE's MPC&A program.[13] (See Figure 5.1.)

This level of rapid upgrades falls far short of expectations: in early 2002, the program projected that rapid upgrades on 42% of the nuclear material would be completed by the end of FY 2002.[14] The difference is accounted for by much slower than expected progress in completing rapid upgrades in the defense complex of Russia's Ministry of Atomic Energy (MINATOM), where most of Russia's nuclear material resides. (See Figure 5.3 for a breakdown of progress in accomplishing upgrades by the different categories of facilities covered in the program.) While 37% of the material had rapid upgrades completed, only 17% had comprehensive upgrades installed.[15]

Several caveats for these percentages should be kept in mind:

Figure 5.1 – Status of Security Upgrades on Russian Weapons-Usable Nuclear Material



- **Sites vs. materials.** If one judges not by the fraction of material covered by upgrades, but by the fraction of sites, more than half of the job is done. This is because the program focused on upgrading the small, vulnerable sites first – sites that probably posed the most urgent proliferation threats. The upgrades at these sites reduced a substantial fraction of the proliferation threat, but the contribution they made to the figures above on the total amount of material covered was minor, since these completed facilities have

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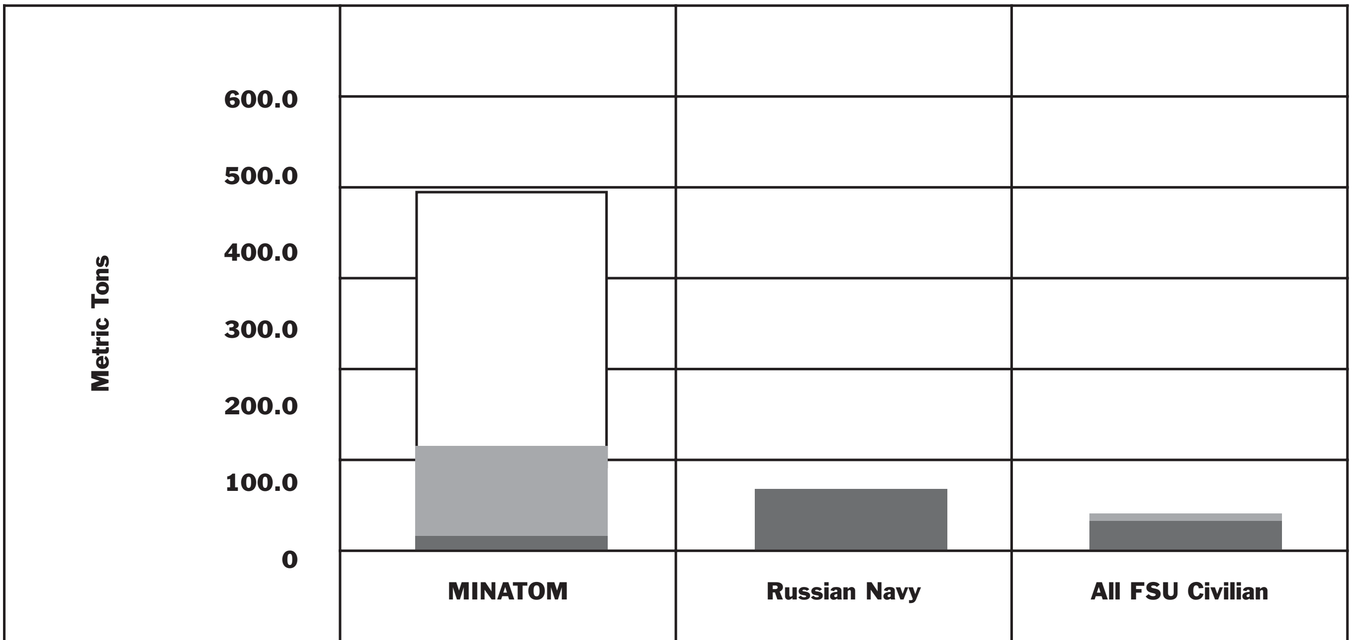
[13] The 37% figure is the program's latest assessment. (Personal communication from DOE official, March 2003). All figures on upgrades for nuclear materials in the text and figures are derived from figures offered in DOE, *FY 2004 Detailed Budget Justifications—Defense Nuclear Nonproliferation* (Washington, D.C.: DOE, February 2003; available at http://www.mbe.doe.gov/budget/04budget/content/defnn/nn.pdf as of February 5, 2003), updated by this personal communication. The budget justifications reported that rapid upgrades had been completed for 20% of the 500 tons of potentially vulnerable weapons-usable nuclear material in the Ministry of Atomic Energy (MINATOM) defense complex, 100% of the 60 tons of material in the Navy complex, and 98% of the 40 tons of material in the civilian complexes in Russia and the other former Soviet states. Since those justifications were prepared, the estimate of the fraction of MINATOM defense complex material with rapid upgrades completed has increased. For a detailed discussion of the MPC&A program, see Matthew Bunn, "Material Protection, Control, and Accounting," *Controlling Nuclear Warheads and Materials* (available http://www.nti.org/e_research/cnwm/securing/mpca.asp as of March 12, 2003).

[14] DOE, *FY 2003 Detailed Budget Justifications—Defense Nuclear Nonproliferation* (Washington, D.C.: DOE, February 2002; available at http://www.mbe.doe.gov/budget/03budget/content/defnn/nuclnonp.pdf as of February 5, 2003), pp. 22, 118–120. In our previous report, in May 2002, we reported that rapid upgrades for roughly 40% of the potentially vulnerable nuclear material in the former Soviet Union had been completed. We based this on interviews with program personnel at the time, and on this 42% projection from the DOE budget justifications. Similar estimates – though scaled back to an expectation of 40% of material with rapid upgrades completed by the end of FY 2002, were included in U.S. Department of Energy, "The MPC&A Scorecard: Nuclear Material," presented in Jack Caravelli, Kenneth Sheely, and Brian Waud, "MPC&A Program Overview: Initiatives for Acceleration and Expansion," in *Proceedings of the 43rd Annual Meeting of the Institute for Nuclear Materials Management, Orlando, Florida, June 23–27, 2002* (Northbrook, Illinois: INMM, 2002). Indeed, the program has been scaling back its estimates of the level of upgrades completed for years: for example, the program told the General Accounting Office that rapid upgrades had been completed for 32% of the potentially vulnerable nuclear material in Russia in February 2001 – more than the program now believes had been completed by October 2001. See U.S. Congress, General Accounting Office, *Nuclear Nonproliferation: Security of Russia's Nuclear Material Improving; Further Enhancements Needed, GAO-01-312* (Washington, D.C.: GAO, February 2001; available at http://www.gao.gov/new.items/d01312.pdf as of February 25, 2003).

Figure 5.2 – Status of Security Upgrades for Different Categories of Former Soviet Facilities



	MINATOM	Russian Navy	All FSU Civilian
Cooperative Upgrades Not Completed	377.0	0.0	0.8
Rapid Upgrades	103.0	1.2	17.6
Comprehensive Upgrades	20.0	58.8	21.6

small amounts of material. Indeed, for judging both the fraction of the risk reduced and the fraction of the total work done (in dollars or person-hours), the number of buildings completed is a far better metric than the percentage of material covered – but unfortunately the program has not publicly provided recent data at the building level. (The program has reported, however, that by October 2002, its consolidation effort had succeeded in cleaning out the vulnerable nuclear material entirely from 21 of 55 buildings in Russia from which it hopes to remove such material – out of over 250 such buildings that exist in Russia.[16]) Comprehensive upgrades have already been completed at all of the facilities with weapons-usable nuclear material in the non-Russian states of the former Soviet Union, and within Russia, "rapid upgrades" have been completed for nearly all of the known civilian facilities with weapons-usable nuclear material, and "comprehensive upgrades" for 98% of the material at these sites are expected to be completed in FY 2003.[17] (See Figure 5.5 for the number of sites where comprehensive upgrades have been completed; site-level data on completion of rapid upgrades is not publicly available.)

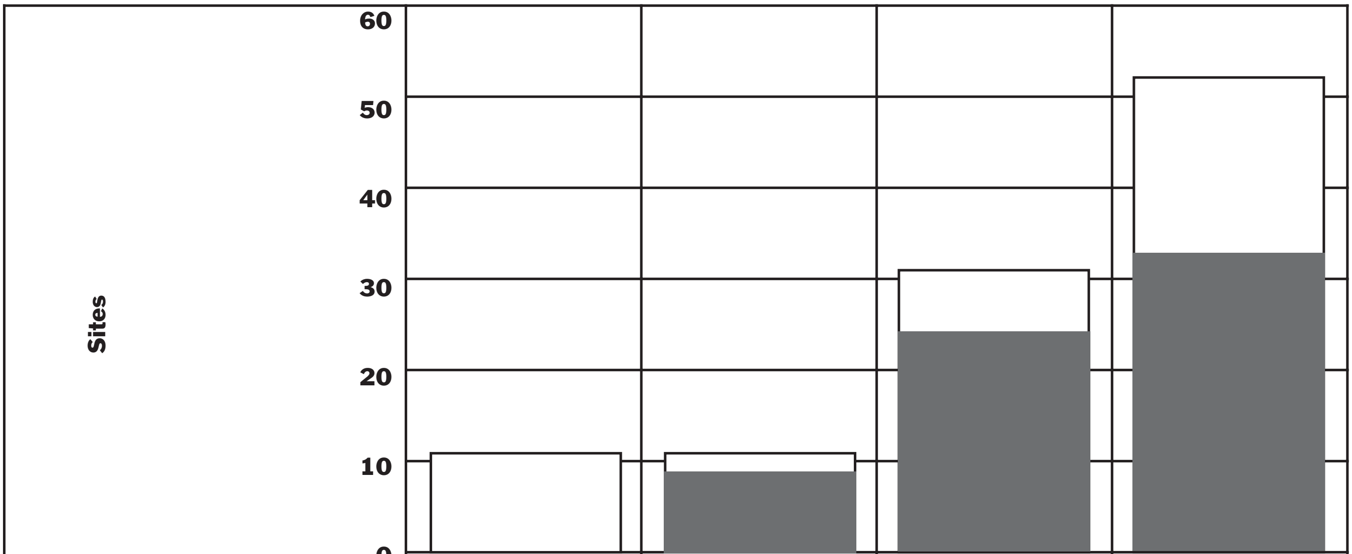
- **Protection of material not yet covered.** An obvious question is: how secure is the 63% of the material not yet covered by upgrades? It is

[15] See DOE, *FY 2004 Detailed Budget Justifications—Defense Nuclear Nonproliferation*, op. cit., p. 624, updated by personal communication with DOE official, March 2003.

[16] See DOE, *FY 2004 Detailed Budget Justifications—Defense Nuclear Nonproliferation*, op. cit., p. 647; the over 250 total is from GAO, *Nuclear Nonproliferation: Security of Russia's Nuclear Material Improving; Further Enhancements Needed*, op. cit.

[17] See DOE, *FY 2004 Detailed Budget Justifications—Defense Nuclear Nonproliferation*, op. cit., p. 644.

Figure 5.3 – Status of Security Upgrades for Sites with Weapons-Usable Material within the Former Soviet Union



	MINATOM	Russian Navy	All FSU Civilian	TOTAL
Cooperative Upgrades Not Completed	11	2	7	20
Comprehensive Upgrades Completed	0	9	24	33

certainly possible that Russia, by its own efforts, has managed to provide protection for some of this material that is as good or better than what exists for some of the material that has been covered in the cooperative upgrade program. If so, that would not increase the number of security upgrades U.S. programs could take credit for, but it would decrease the amount of the total job left to be done, increasing the fraction represented by the work already accomplished. The overwhelming majority of this not-yet-covered material is at large nuclear weapons complex sites – in particular, the four nuclear warhead assembly and disassembly facilities in Russia, and the two facilities where plutonium and HEU weapons components were fabricated. At those buildings and facilities where the United States and Russia have agreed on procedures for access and assurances that the U.S.-funded work is being done appropriately, upgrades have at least begun. As of October 2002, upgrades were underway for an additional 43% of Russia's potentially vulnerable nuclear material – leaving only 20% with no cooperative upgrades at all yet underway.[18] This "underway" category is very broad, however, including everything from sites where work has only just begun and no significant reductions in risk have yet been accomplished, to areas where rapid upgrades will soon be complete. The material for which upgrades are not even underway is largely in buildings that U.S. experts have not yet been allowed to visit, and so little is known about the specifics of the security and accounting arrangements at these buildings. On the one hand, the nuclear weapons complex facilities where most of this material resides are all protected by armed troops and multiple layers of fences; they would not be easy targets for terrorist teams attempting to shoot their way in. On the other hand, at every facility where U.S. and Russian experts have cooperated on MPC&A to date, including nuclear weapons complex facilities and nuclear weapon storage facilities, they have

[18] Personal communication from DOE official, January 2003.

agreed that major upgrades were needed, including both better protection against covert insider theft, and upgraded measures to protect against armed attack by outsiders (ranging from better intrusion detectors to means for guards to communicate with each other and hardened positions for them to fight off attackers from). The short answer is that we simply do not know how well protected this not-yet-covered material is.

- **Sustainability.** Installation of effective equipment is necessary but not sufficient for providing good security and accounting. As noted earlier, success in improving security and accounting for nuclear materials requires success in changing the way the people who manage and guard these materials do their business day to day, and that is both difficult to do and difficult to measure. A recent Russian survey of more than a dozen sites participating in the MPC&A program provides some suggestive indication that there is much more to be done on sustaining security for the long haul: all of the sites that responded expressed doubts about their ability to maintain adequate security once U.S. assistance phases out in the future, and all were relying on continued U.S. funds to buy effective tamper-indicating seals and to operate their computerized accounting systems.[19] Hence, a rating based solely on the fraction of material equipped with upgrades is inevitably an overestimate of the fraction of the total work that has been accomplished, since it ignores the work above and beyond the initial installation of equipment.

- **Adequacy in defeating plausible threats.** The systems being installed in the MPC&A program are intended to defeat rather modest threats – a single insider, a small number of well-trained and well-armed outsiders, or both working together. Against larger threats – several insiders working together, or a large terrorist attacking force (such as the one that seized a theater in Moscow in late 2002), they would not be likely to be sufficient. If a policy decision were made that systems able to defeat larger threats should be installed, then the fraction of the job that could be judged as "done" would be greatly reduced.

Nuclear material in the former Soviet Union: rate of progress. In the year following the September 11 attacks, the United States and Russia made substantial efforts to accelerate their cooperation in security and accounting for nuclear materials. The U.S. and Russian Presidents agreed to give "urgent attention" to the matter; the U.S. Secretary of Energy and the Russian Minister of Atomic Energy agreed to work together to accelerate the effort; a new access agreement was signed that cleared the way for work to resume or begin at several sensitive locations; and new initiatives were launched to speed the processing of contracts, begin consolidating material at large sites into central storage facilities, and undertake comprehensive, rather than building-by-building approaches to upgrading security and accounting at some of Russia's largest facilities. Nevertheless, in the fiscal year immediately following the September 11 attacks, according to DOE's own data, rapid upgrades were completed on only an additional 9% of Russia's potentially vulnerable nuclear material (going from 28% to 37%), and comprehensive upgrades were completed on only 2% of this material (going from 15% to 17%).[20] During that year, in fact, DOE significantly scaled back its projections of the rate of future progress: as of April 2002, the program was projecting that rapid upgrades would be completed for 77% of the potentially vulnerable nuclear material in Russia by the end of FY 2004, while by February 2003 this figure had been scaled back to 58%.[21] Only 26% of the material is

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[19] See Gennadi Pshakin, Vladimir Samsonov, and Victor Erastov, *U.S.-Russian Collaboration on Nuclear Materials Protection, Control, and Accounting* (Obninsk, Russia: Analytical Center on Nonproliferation, Institute for Physics and Power Engineering, 2002).

[20] Figures derived from figures provided for MINATOM defense, naval, and civilian facilities in DOE, *FY 2004 Detailed Budget Justifications—Defense Nuclear Nonproliferation*, op. cit., pp. 633–644, updated by personal communication with DOE official, March 2003.

[21] See "The MPC&A Scorecard: Nuclear Material," op. cit.; and DOE, *FY 2004 Detailed Budget Justifications—Defense Nuclear Nonproliferation*, op. cit., pp. 633–644.

expected to have comprehensive upgrades in place by then. Yet DOE has not changed its goal, established soon after September 11, of completing comprehensive upgrades for all potentially vulnerable nuclear material in the former Soviet Union by the end of 2008. Clearly a dramatic acceleration of the effort is needed to achieve that goal – still more, if the shorter timetables recommended in this report are to be met.

Nuclear warheads in the former Soviet Union: fraction secured. As of the end of FY 2002, sites containing nearly all of the estimated 4,000 naval warheads in the former Soviet Union (one-fifth of the estimated 20,000 total warheads that still exist) had had "rapid upgrades" of security and accounting systems put in place, in DOE's MPC&A program (see Figure 5.4).[22] In addition, "quick fix" security fencing had been installed at 47 of over 120 other warhead bunkers, as part of the Department of Defense's Cooperative Threat Reduction warhead security effort.[23] If the non-naval warheads were spread evenly among these bunkers, this would represent almost 40% of the roughly 16,000 non-naval warheads (see Figure 5.5). The total would then be roughly half of Russia's nuclear warheads that have had some substantial form of initial security upgrades installed. In fact, however, the 47 bunkers where quick-fix fencing is installed are mostly not at the major national storage sites where most of Russia's nuclear weapons are stored, so the actual number of warheads secured is probably less than this one-half figure. Progress on comprehensive upgrades has been much slower: these have been completed for some 40% of the naval warheads,[24] and none of the remaining warheads – in large part, for the non-naval warheads, because of disputes over access to these sensitive sites. Hence, only 8% of Russia's total stockpile of warheads yet has comprehensive upgrades installed.

Like the figures for materials, these estimates of "fraction covered" provide only a very rough estimate of how much of the job has been done, subject to numerous caveats. As in the material case, there are serious issues related to whether the security provided by these upgrades is sufficient to meet post–September 11 threats, and whether it will be sustained for the long haul. But as in the case of nuclear materials, there is also an enormous amount of work that has been done that is not reflected in these figures – including extensive programs focused on improving security during warhead transport, the establishment of a national training and equipment testing center, the provision of equipment for personnel screening, real-time computerized accounting of warheads, and emergency response, and more. Nevertheless, the fraction of warheads provided with security upgrades provides as good a metric of overall progress as is currently available.

Nuclear warheads in the former Soviet Union: rate of progress. Progress in securing Russia's naval warheads has been quite rapid – effectively all of these warheads were provided with rapid security upgrades in the first three years of the effort. Sixty percent of them are expected

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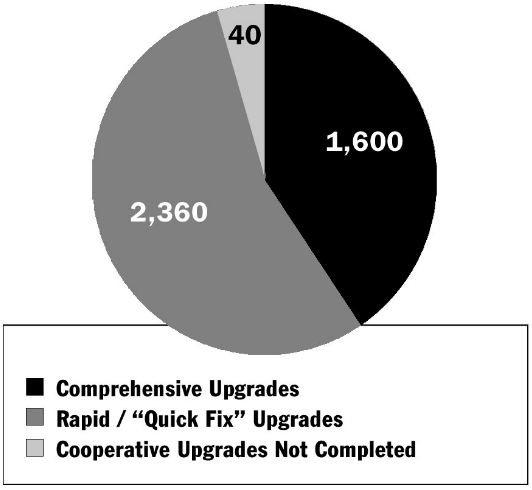
[22] See DOE, *FY 2004 Detailed Budget Justifications—Defense Nuclear Nonproliferation*, op. cit., p. 634, and U.S. Department of Energy, "The MPC&A Scorecard: Russian Navy Nuclear Warheads," presented in Caravelli, Sheely, and Waud, "MPC&A Program Overview," op. cit.

[23] This was the figure for quick fix systems installed and operation provided to the Department of Defense by the Russian Ministry of Defense in April 2002. See Defense Threat Reduction Agency, "Site Security Enhancements (Quick Fix)," (available at http://www.dtra.mil/ctr/project/projrus/ctr_quickfix.html as of February 5, 2003, last updated January 6, 2003). For detailed discussions of warhead security upgrade efforts, see Matthew Bunn, "Warhead Security," *Controlling Nuclear Warheads and Materials* (available at www.nti.org/e_research/cnwm/securing/warhead.asp as of March 12, 2003); Charles L. Thornton, "The Nunn-Lugar Weapons Protection, Control, and Accounting Program: Securing Russia's Nuclear Warheads," in *Proceedings of the 43rd Annual Meeting of the Institute for Nuclear Materials Management, Orlando, Florida, June 23–27, 2002* (Northbrook, Illinois: INMM, 2002); and William Moon, "CTR Russian Weapons of Mass Destruction (WMD) Security Program," (paper presented at the National Defense Industries Association National Security Division, Reston, Virginia, June 27, 2002; available at http://www.dtic.mil/ndia/2002security/moon.pdf as of February 5, 2003).

[24] See DOE, *FY 2004 Detailed Budget Justifications—Defense Nuclear Nonproliferation*, op. cit., p. 624.

to be in facilities with comprehensive upgrades by the end of FY 2003, and 90% by the end of FY 2004; comprehensive upgrades are expected to be completed in 2006.[25] Progress on upgrades at the storage sites for the remaining warheads, however, has been nearly at a standstill for years – though the problems that have created that roadblock may now be on the road to resolution.[26] The completion date for upgrades at these non-naval sites will depend on progress in resolving these roadblocks, and on the number and capabilities of Russian firms that can be contracted to do the upgrade work – but comprehensive upgrades at warhead storage facilities are not expected to be complete until 2012.[27] The same DOE-funded national laboratory team that has been implementing upgrades for Russian naval warhead sites is now beginning to work at Strategic Rocket Forces sites; conceivably, that work may expand to other warhead sites and contribute to accelerating completion of upgrades at these facilities.[28] Clearly in this case, as well, a drastic acceleration will be needed if the goals outlined in this report are to be achieved.

Figure 5.4 – Status of Security Upgrades for Russian Naval Warheads



Nuclear material outside the former Soviet Union: fraction secured or removed. As described earlier, there are also large numbers of facilities outside the former Soviet Union where nuclear materials may be inadequately secured. Defining metrics for assessing progress here is even more difficult, as efforts to address this issue are dispersed and focus on widely varying goals, from converting HEU-fueled research reactors to use low-enriched uranium, to reviewing and upgrading security at individual facilities.[29] Perhaps the most useful metric is the fraction of those facilities that the U.S. government itself has identified as the most vulnerable facilities from which HEU or plutonium should simply be removed, where this has in fact been accomplished. The U.S. government sponsored three such nuclear material removal operations by the end of 2002 – Project Sapphire, which airlifted nearly 600 kilograms of HEU from Kazakhstan to secure storage in Tennessee in 1994; Project Auburn Endeavor, which removed several kilograms of HEU from Georgia to the United Kingdom in 1998; and Project Vinca, which removed 48 kilograms of 80% enriched HEU from a vulnerable facility in Yugoslavia in 2002.[30] The U.S. government has identified 24 additional sites that it believes are high proliferation risks from which material should be removed.[31] By this metric, with three of the most vulnerable sites completed and 24 more to go, just over 11% of the job has been accomplished.

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[25] See DOE, *FY 2004 Detailed Budget Justifications—Defense Nuclear Nonproliferation*, op. cit., p. 624. As with nuclear material, DOE has become notably less optimistic about near-term progress in the last year – as of April 2002, the projection was that comprehensive upgrades would be completed for 75% of the warheads by the end of FY 2003, not 60%. See "The MPC&A Scorecard: Russian Navy Nuclear Warheads," op. cit.

[26] See discussion in "Warhead Security," op. cit.

[27] See Defense Threat Reduction Agency, "Site Security Enhancements," December 30, 2002 (available at http://www.dtra.mil/ctr/project/projrus/ctr_site_security.html as of February 5, 2003).

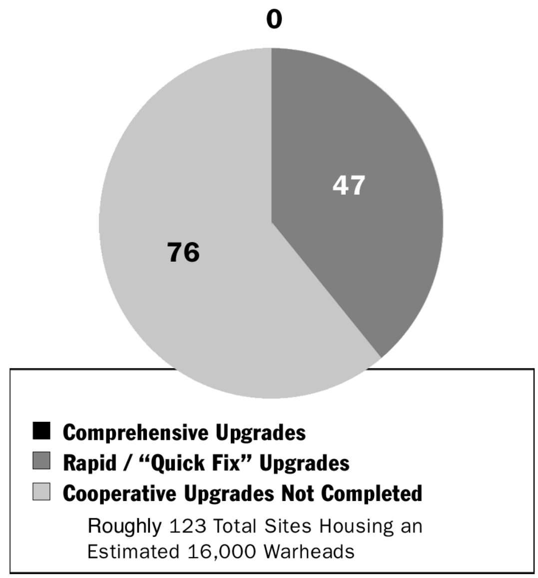
[28] See DOE, *FY 2004 Detailed Budget Justifications—Defense Nuclear Nonproliferation*, op. cit., pp. 637–638.

[29] See discussions in Matthew Bunn, "Removing Material From Vulnerable Sites," *Controlling Nuclear Warheads and Materials* (available at http://www.nti.org/e_research/cnwm/securing/vulnerable.asp as of March 12, 2003), and Matthew Bunn, "International Nuclear Security Upgrades," *Controlling Nuclear Warheads and Materials* (available at http://www.nti.org/e_research/cnwm/securing/secure.asp as of March 12, 2003).

Here, too, there are important caveats to note. First, security has been at least modestly upgraded in cooperative programs – some bilateral, some under International Atomic Energy Agency (IAEA) auspices – at a number of sites around the world where material has not been removed, and these are not counted in the above total. Second, material has been removed from dozens of research reactors that once had HEU, when those reactors converted to use LEU fuel; while those facilities may not have made it onto the list of most vulnerable facilities around the world, nonetheless, removing the HEU from them and eliminating the need for additional shipments of fresh HEU to them has significantly reduced nuclear proliferation and terrorism risks. Third, two of the three operations to remove material from high-risk sites that have been conducted so far were actually within the states of the former Soviet Union, and a number of the 24 additional sites are believed to be also – so if the focus were kept strictly on facilities outside the former Soviet Union, the number accomplished would be only one, but the total number remaining to be accomplished would be smaller than 24. Fourth, there are dozens of facilities around the world where either substantial security upgrades or removal of the warheads or materials are needed, which are not included on the U.S. government's list of the 24 most urgent facilities.

Nuclear material outside the former Soviet Union: rate of progress. To date, removals of nuclear material from the most vulnerable sites have been occurring at the rate of one every four years (one in 1994, one in 1998, and one in 2002). At that rate, it would take almost a century to clean out the remaining 24 identified high-risk facilities. Under a new U.S.-Russia-IAEA tripartite initiative to bring vulnerable Soviet-supplied material back to Russia, this rate might increase significantly. DOE projects that HEU from one additional site (a research reactor in Uzbekistan) will be sent back to Russia in FY 2003, and as much as 100 kilograms of fresh and spent HEU fuel would be sent back to

Figure 5.5 – Status of Security Upgrades for Russian Non-Naval Warhead Bunker Sites



Russia by the end of FY 2004.[32] No specific target date for completing this effort has been announced. If the rate continued at an average of one site per year, it would still require a quarter century to finish the job. Hence, we recommend the creation of a "Global Cleanout" program focused on removing all nuclear material from the world's most vulnerable sites as rapidly as practicable, with the goal of removing all nuclear material from the world's most vulnerable sites within a few years.[33]

Interdicting Nuclear Smuggling

Developing metrics for the goal of interdicting nuclear smuggling is difficult, as there are many elements to accomplishing the job – providing adequate capabilities to detect nuclear materials being smuggled across borders, establishing appropriate police and intelligence units in the relevant countries trained and equipped to deal with nuclear smuggling cases, creating stronger legal infrastructures so that nuclear thieves and smugglers face a

[30] See discussion of these cases in Bunn, "Removing Nuclear Material From Vulnerable Sites," op. cit.

[31] Robert Schlesinger, "24 Sites Eyed for Uranium Seizure," *Boston Globe*, August 24, 2002.

[32] See DOE, *FY 2004 Detailed Budget Justifications—Defense Nuclear Nonproliferation*, op. cit., p. 596.

[33] See "Global Cleanout," p. 143.

greater chance of a larger punishment, expanding international intelligence and police cooperation focused on the nuclear smuggling threat, 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 – the list goes on.

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

- to ensure that 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 able to detect smuggled nuclear weapons or materials.

Measuring progress in these two areas makes it possible to assess how much of at least the initial steps in addressing nuclear smuggling has been accomplished. This should not be misinterpreted, however, to suggest that the job would be done when each of these figures reached 100%; even more than with the previous metrics, there are a huge number of complications and other aspects to consider in forming a complete judgment of how completely and how well this job is getting done. As just one example, consider the problem of corruption, endemic in border control and customs forces in much of the relevant region: a good nuclear detector and training in how to use it will not do much good if the customs inspector will look the other way for a bottle of vodka. (Fortunately, many nuclear smuggling interdiction efforts are designed to take such factors into account – for example by sending video and readings from the nuclear detector to a central post as well as to the guard who is with the detector and available to be bribed.)

Key border posts trained and equipped to detect nuclear smuggling: fraction accomplished. As of the end of FY 2002, roughly one-third of the 60 border crossings within Russia itself that had been identified as most critical had been provided with appropriate training and equipment to address nuclear smuggling, as part of DOE's Second Line of Defense program.[34] The Department of Energy, however, has now estimated that a much larger total number of border points – 393 sites in Russia and 21 other nearby countries – will ultimately require installation of similar equipment.[35] Anti-nuclear smuggling efforts sponsored by the Departments of Defense and State have provided training and equipment for key law enforcement and border control personnel, including installation of radiation detection equipment at additional sites.[36] Installation of equipment at border crossings, however, has not been as central a focus of these programs – and similar data on the number of border crossings covered by these efforts is not publicly available.[37] Overall, it appears very likely that the fraction of the identified set of border crossings that have been equipped with appropriate equipment and trained personnel is under 15 percent.

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[34] The Department of Energy has been the lead federal program for installing radiation detection equipment inside Russia. It originally targeted 60 sites for upgrades in the Second Line of Defense program; see U.S. General Accounting Office (GAO), *Nuclear Nonproliferation: U.S. Assistance Efforts to Help Other Countries Combat Nuclear Smuggling Need Strengthened Coordination and Planning, GAO-02-426* (Washington, D.C.: GAO, May 2002; available at http://www.gao.gov/new.items/d02426.pdf as of January 29, 2003), p. 6. For the figure of 20 sites completed by the end of FY 2002, see DOE, *FY 2004 Detailed Budget Justifications—Defense Nuclear Nonproliferation*, op. cit., pp. 658.

[35] See DOE, *FY 2004 Detailed Budget Justifications—Defense Nuclear Nonproliferation*, op. cit., p. 658. 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.

[36] As a measure of consolidation and efficiency, DOE's Second Line of Defense program has taken over the maintenance and improvement of the radiation detection equipment previously installed at border crossing in State-Department funded programs, which exists in 19 different countries outside Russia. See DOE, *FY 2004 Detailed Budget Justifications—Defense Nuclear Nonproliferation*, op. cit., p. 659. Second Line of Defense is concentrating its own efforts in Russia, Ukraine, and Kazakhstan.

Key border posts trained and equipped to detect nuclear smuggling: rate of progress. In most cases, U.S. nuclear smuggling interdiction programs have had excellent cooperation with recipient states,[38] and have therefore been providing training and installing equipment as fast as they had the funding to do so. DOE's Second Line of Defense program intends to equip another 37 sites – roughly an additional 10% of the identified total – during FY 2003 and FY 2004.[39] Data on the pace at which other U.S. and international programs intend to equip additional sites during that period is not publicly available, but the total pace all programs in installing radiation detection equipment at border points may amount to roughly twice the pace of the DOE effort alone. No estimated completion date for these programs has been published. Within the U.S. government, a comprehensive interagency plan assistance to counter nuclear smuggling, including a section on assistance for radiation detection at borders, is reportedly nearing completion.[40]

Sites shipping to the United States trained and equipped to detect nuclear smuggling: fraction accomplished. For nuclear contraband, it is important not to rely on inspections after cargo and baggage have already arrived at U.S. ports, airports, or border crossings, as a bomb set off there, before inspectors could get to it, could have devastating consequences (especially in a U.S. harbor or airport). Hence, under the U.S. Customs Service's Container Security Initiative, the United States plans to cooperate with other countries to put in place nuclear inspection capabilities at the major ports that ship cargo to the United States, so that it can be inspected before it leaves. (Equipment and expertise for this effort is coming from DOE's Second Line of Defense program.) This will take some time to accomplish, however; to date, none of the sites shipping cargo to the United States have such nuclear inspection capabilities and procedures in place.[41]

There are a substantial number of customs posts within the United States that have at least some equipment and training to detect nuclear materials, but much of this equipment has modest capabilities: the "radiation pagers" worn by many customs inspectors, for example, would do very well in detecting intensely radioactive material for a "dirty bomb," but would have no chance of detecting the very weak radiation from HEU for a nuclear bomb, with even as much shielding as the lead bags used to protect film going through a scanner.[42] Indeed, by chance the depleted uranium that ABC News smuggled into the United States in an experiment was in one of the few large cargo containers entering the United States that was inspected – but the uranium, enough for a bomb had it been highly enriched, was not detected in

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[37] For discussions of the main U.S. and international programs to assist states in improving their capabilities to stop nuclear smuggling, see Anthony Wier, "Interdicting Nuclear Smuggling," *Controlling Nuclear Warheads and Materials* (available at http://www.nti.org/e_research/cnwm/interdicting.asp as of March 12, 2003).

[38] In part, this is because the customs and border control agencies in recipient countries have a financial incentive to make effective use of this equipment – in stark contrast to the financial drag represented by maintaining high security at nuclear sites. This is because the radiation detection capabilities allow them to detect radioactive materials whose export would have been legitimate, but whose characteristics have been inaccurately described and value under-reported, in an attempt to avoid duties – allowing these agencies to generate additional revenues from duties and fines on such items. As a result, prospects for sustainability of this equipment are also believed to be good, since the recipient agencies have an incentive to maintain it and see that it is effectively used. (Interviews with Customs and DOE officials, 2001 and 2002.)

[39] See DOE, *FY 2004 Detailed Budget Justifications—Defense Nuclear Nonproliferation*, op. cit., p. 658.

[40] Interviews with State Department and Department of Energy officials, February 2003. The General Accounting Office had previously criticized the government for lacking such a comprehensive plan. See GAO, *Nuclear Nonproliferation: U.S. Assistance Efforts to Help Other Countries Combat Nuclear Smuggling Need Strengthened Coordination and Planning*, op. cit.

[41] For a useful discussion, see JayEtta Z. Hecker, General Accounting Office, "Container Security: Current Efforts to Detect Nuclear Materials, New Initiatives, and Challenges," testimony to the House Committee on Government Reform, Subcommittee on National Security, Veterans Affairs, and International Relations, November 18, 2002 (available at http://www.gao.gov/new.items/d03297t.pdf as of January 21, 2003).

the inspection.[43] As of the end of FY 2002, the U.S. Customs Service had deployed 101 "large-scale x-ray and gamma ray systems that assist inspectors in screening cargo containers and conveyances for potential terrorist weapons, including nuclear weapons and radiological materials."[44] Customs was also planning to install some 400 portal monitors – radiation detectors that would be capable of scanning entire cars, trains, or cargo containers – but as of the end of FY 2002, none of these were yet in place at U.S. border entry points.[45]

Sites shipping to the United States trained and equipped to detect nuclear smuggling: rate of progress. The U.S. Customs Service has only just begun the process of negotiations with other states with ports and sites that ship cargo to the United States, and testing of equipment for cargo inspection is under way now. It is therefore too early to judge how long it will take to ensure that sites shipping large quantities of cargo to the United States have personnel appropriately trained and equipped to detect nuclear smuggling.

Stabilizing Employment for Nuclear Personnel

Developing metrics for assessing how much progress has been made in stabilizing the personnel with access to nuclear weapons, materials, and expertise is complicated by the fact that these programs have a number of quite different goals, and the emphasis among them has shifted over the years. Initially, the idea was to provide short-term grants on an emergency basis to make sure that key weapons scientists did not become desperate enough to sell their knowledge during what was expected to be a short-term crisis before Russia got back on its feet. The mission of providing short-term grants to ease desperation (and to fund desirable research) continues to be an important one – but as time went on after the collapse of the Soviet Union, it became clear that the emphasis had to shift to two new missions: reducing Russia's weapons complexes to sizes appropriate to their post–Cold War missions, affordable for Russia to sustain over the long haul; and providing permanent, non-subsidized jobs to thousands of weapons of mass destruction scientists and workers who were no longer needed. Given the very difficult economic picture in Russia since the collapse of the Soviet Union, and the many disagreements that have emerged between the United States and Russia over closing nuclear, chemical, and biological facilities, both of these two tasks have proved to be extremely challenging.

Key nuclear weapons scientists given short-term grants: fraction accomplished. Although it took some time for key programs such as the International Science and Technology Centers (ISTC) to get up and running on a large scale – and Russian nuclear weapons scientists endured some extremely difficult times in the interim – the mission of easing desperation for key nuclear weapons scientists was largely accomplished in the mid- and late-1990s. It is impossible to assess exactly what fraction of the most proliferation-sensitive nuclear weapons scientists who may have been in need of additional funding for non-weapons research in fact received it, because Russia and the United States have never cooperated to compile a list of who the people with the most critical weapons knowledge are. Nevertheless, from anecdotal information, including discussions with Russian weapons experts

[42] See John P. Holdren and Matthew Bunn, "Technical Background: A Tutorial on Nuclear Weapons and Nuclear Explosive Materials," *Controlling Nuclear Warheads and Materials* (available at http://www.nti.org/e_research/cnwm/overview/technical.asp as of March 12, 2003).

[43] See Christopher Paine, "Preventing Nuclear Terrorism," testimony to the House Committee on Government Reform, Subcommittee on National Security, Veterans Affairs, and International Relations, 107th Congress, 2nd Session, September 24, 2002 (available at http://www.house.gov/reform/ns/schedule_107th_2nd_session/paine_sept_24.htm as of January 21, 2003).

[44] Testimony by Jayson P. Ahern, U.S. Customs Service, testimony to the House Committee on Government Reform, Subcommittee on National Security, Veterans Affairs, and International Relations, November 18, 2002 (available at http://reform.house.gov/ns/schedule_107th_2nd_session/ahern_nov_18.htm as of February 6, 2003).

[45] Hecker, "Container Security," testimony, op. cit.

regarding which of them participated in ISTC or similar projects, it appears that in the nuclear sector at least, these projects reached a large fraction of those most in need of them – perhaps 70–80%.[46] It may well be that a large number of serious proliferation incidents were averted as a result.

Key nuclear weapons scientists given short-term grants: rate of progress. On this metric (if not on others) the effort in the nuclear sector has more or less stabilized. No clear target for ending the effort has been identified. Today, in any case, Russian nuclear weapons scientists are being paid on time, and paid enough to live on – the degree of potential desperation (at least for those who will continue to have employment in the weapons complex) has been substantially reduced.[47] Excess nuclear weapon scientists and workers provided sustainable civilian work: fraction accomplished. Over the next several years, Russia plans to reduce the workforce in its nuclear weapons programs by 35,000 people, nearly half of the total.[48] Thousands of these nuclear weapons scientists and workers are likely to retire, thousands more are likely to find other work without help, and thousands more are likely to be re-employed in civilian nuclear projects or other conversion projects sponsored by MINATOM. The remaining need may be in the range of 15,000–20,000 jobs. To date, U.S. programs have had real but modest success in creating sustainable, long-term civilian jobs for Russian weapons experts – and the degree of this success is difficult to judge because adequate data is not available. In the case of the Nuclear Cities Initiative (NCI), for example, only about 400 jobs have been created in specific NCI-sponsored projects, but the European Bank for Reconstruction and Development (EBRD), after NCI helped the bank establish offices in several of the nuclear cities, has given out almost a thousand small business loans there, which have probably created several thousand jobs – though no one has attempted to count them. Similarly, ISTC and the Initiatives for Proliferation Prevention (IPP) program have each resulted in the establishment of commercial enterprises employing many hundreds of people, but data is not publicly available on how many of these are former nuclear weapons scientists or workers (both of these programs address chemical, biological, and aerospace experts as well, and these commercial enterprises, once fully established, presumably hire whoever is best for their jobs, regardless of whether the new hires were once associated with weapons of mass destruction or not). Even if one assumes that, counting the EBRD loans, these programs have created 4,000 jobs that all went to former nuclear weapons scientists and workers (surely an overestimate of the actual degree of success), this would still represent some 20% of the need.[49]

Other U.S.-funded programs not directly focused on job creation have also led to the creation of large numbers of jobs. The most important of these is the U.S.-Russian HEU Purchase Agreement. Several thousand Russian nuclear experts and workers are directly employed on the various steps of fulfilling this contract – and are therefore not included among those for whom other U.S., Russian, or international programs have to provide other employment. The total number of jobs specifically for nuclear experts and workers created by this means is probably larger than the combined total from all the programs specifically focused on job creation. Moreover, MINATOM officials have

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[46] The fraction is likely much less in the chemical and (especially) biological areas, where the sensitivities were even higher; some key biological facilities have not yet been opened to the West, and therefore the scientists who still work at these facilities have not been eligible to participate in programs such as ISTC.

[47] For discussion, see Matthew Bunn, "The Threat in Russia and the NIS," *Controlling Nuclear Warheads and Materials* (available at http://www.nti.org/e_research/cnwm/threat/russia.asp as of March 12, 2003).

[48] Oleg Bukharin, Frank von Hippel, and Sharon K. Weiner, *Conversion and Job Creation in Russia's Closed Nuclear Cities: An Update Based on a Workshop Held in Obninsk, Russia, June 27–29, 2000* (Princeton, N.J.: Princeton University, November 2000; available at http://www.princeton.edu/~globsec/publications/pdf/obninsk1.pdf as of January 21, 2003).

[49] For a similar (though even more pessimistic) assessment of the degree of success to date in job creation, see J. Raphael della Ratta, "A Strategy for the Redirection of the Russian Nuclear Complex," in *Reshaping U.S.-Russian Threat Reduction*, op. cit.

indicated that the funding for MINATOM's own roughly $50 million per year conversion program in its nuclear weapons complex comes primarily from the HEU purchase – as does funding for dealing with nuclear waste from dismantled submarines, and for cleanup in MINATOM's nuclear complex[50] – and they have estimated that from 1998 through 2001, this conversion program had created over 8,000 jobs in Russia's nuclear complex.[51] Since Russia has funded this program itself – choosing to use revenue from the HEU purchase for that purpose – we have not counted these jobs toward the total created by U.S.-funded programs, but to the extent that they turn out to be sustainable, long-term jobs, they substantially reduce the total requirement for jobs to be created by U.S. or other internationally funded efforts. Other U.S.-funded programs, such as the MPC&A program and programs to develop new monitoring technologies and procedures, are also employing hundreds, if not thousands, of Russian nuclear experts and workers, at least for now, and if regulations, procedures, and other approaches are put in place that result in Russia maintaining a substantial level of effort in these areas after U.S.-funded programs phase out, some of these jobs will be sustainable ones. No data on the number of these jobs, or the fraction judged likely to be continued after U.S. funding phases out, is publicly available.

As noted earlier, jobs directly created in projects sponsored by U.S. programs may not be the most accurate metric: if U.S. programs assist, for example, in improving the business climate and promoting general economic development in Russia's nuclear cities, this may lead to natural growth of jobs that will absorb large numbers of former nuclear weapons workers. For example, the International Development Centers established in Zheleznogorsk and Snezhinsk are helping with local and regional economic planning, business training, matching of businesses to foreign partners, and a wide range of services for new or expanding businesses. But these centers employ very few people themselves, and their impact on other job creation is difficult to assess quantitatively. As noted earlier, appropriate metrics have not been developed for measuring the contribution of U.S. programs to the business climate in the areas where nuclear workers and experts must be re-employed; moreover, beyond these development centers, U.S.-funded programs focused on improving the improving the general business climate in these locations have been extremely modest, and had limited impact.

Excess nuclear weapon scientists and workers provided sustainable civilian work: rate of progress. Some programs, such as IPP, are now reaching a point where past investments in pre-commercial projects are reaching the point of commercialization, increasing the number of jobs created. No data is publicly available on the total number of jobs provided for former nuclear weapons scientists and workers in the last year or two years, but it appears unlikely to have been more than 5% of the total need per year. DOE expects, however, that the combination of NCI and IPP will have created 6,000 jobs for nuclear experts and workers by the end of FY 2004.[52] No planned date for completing these programs has been established.

Nuclear weapons infrastructure eliminated: fraction accomplished. Only one U.S. program, NCI, is specifically focused on closing down excess nuclear weapons infrastructure in Russia. While other facilities are closing without U.S. help, the only facility closed for nuclear weapons work and opened for civilian work under NCI is a portion (some 40%) of the "Avangard" nuclear weapons assembly and disassembly facility in the city of Sarov. Avangard is the smallest of Russia's four nuclear weapons assembly and disassembly facilities; even if it had been as large as the others, 40% of it would amount to some 10% of Russia's total nuclear weapons assembly and disassembly

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[50] See, for example, remarks by then-First Deputy Minister of Atomic Energy Lev Ryabev, quoted and discussed in Bukharin, von Hippel, and Weiner, *Conversion and Job Creation in Russia's Closed Nuclear Cities*, op. cit.

[51] See Ministry of Atomic Energy, *Major Results of Conversion in Defense Complex Enterprises of MINATOM, Russia in 1998–2001* (Moscow: MINATOM, Summer 2002, translated from the original Russian). This represented somewhat more than half the planned figure.

[52] See DOE, *FY 2004 Detailed Budget Justifications—Defense Nuclear Nonproliferation*, op. cit., p. 664.

floor space – and a much smaller fraction of the total floor space of all the different facilities in Russia's nuclear weapons complex.

Nuclear weapons infrastructure eliminated: rate of progress. The reduction of less than 10% of Russia's nuclear weapons infrastructure represented by the Avangard project required several years. There is as yet no agreement for the United States and Russia to cooperate on closing down more of Russia's nuclear weapons complex (though Russia plans to close other facilities on its own). Nevertheless, by the end of FY 2004, DOE hopes to have met more than half of unspecified "nuclear complex reduction targets" at six Russian nuclear weapon facilities, and to have accomplished its complex reduction goals completely at two of those.[53] No specific target date for completing this effort has been announced.

Monitoring Nuclear Stockpiles and Reductions

The obvious metric for judging how much progress is being made in monitoring nuclear warheads and materials is the fraction of these stockpiles that is subject to monitoring. In some cases it is possible to arrange for voluntary declarations of stockpiles even before monitoring is possible, so the fraction of the warhead and materials stockpiles subject to declarations provides an additional preliminary metric. In most cases, U.S.-Russian discussions of formal arrangements for monitoring or declarations have made little progress.

Nuclear weapons and materials subject to declarations: fraction accomplished. Progress on this metric depends in part on how you count. For example, since Russia has agreed to sell the United States 500 tons of HEU from dismantled nuclear weapons, it has effectively declared that it has at least 500 tons of HEU. But it would not be accurate to count this entire 500 tons as "subject to declarations," since no information has been provided as to where this material now is, how many of these weapons have already been dismantled versus how many remain to be dismantled in the future, and the like. This report includes only those stockpiles for which specific declarations including quantities and locations have been made. None of Russia's nuclear warheads fall into this category. For nuclear materials, every year there is another 30 tons of HEU that is blended down, and becomes subject to declarations (and monitoring, as described below) as part of that process; there are some 35 tons of civilian separated plutonium, on which Russia makes declarations to the IAEA each year; and there are some 5–10 tons of plutonium in storage at the sites of Russia's remaining plutonium production reactors, declared (though not released publicly) under the terms of the plutonium production reactor shutdown agreement, for a total of 70–75 tons, roughly 7% of Russia's stockpile of weapons-usable nuclear materials.

Nuclear weapons and materials subject to declarations: rate of progress. As material is loaded into the now nearly completed Mayak Fissile Material Storage Facility, it will effectively come under declarations, since the United States will be informed of how much material is present in the facility; thus, over the next few years, 50 tons of plutonium should be added to the amounts just described. Beyond that, progress in bringing additional weapons or materials under declarations is minimal. There are no current plans or negotiations relating to declarations of warhead stockpiles. The only additional nuclear materials likely to come under a declarations regime soon are the 34 tons of weapons plutonium covered by the U.S.-Russian plutonium disposition agreement. No date for completing monitoring and declarations regimes has been established.

Nuclear weapons and materials subject to monitoring: fraction accomplished. As with declarations, no warheads are currently subject to monitoring. The only materials currently subject to monitoring arrangements that are actually being implemented are the 30 tons of HEU being downblended each year. (In 2002, U.S. experts were permitted to visit and count the cans of plutonium produced in recent years in Russia's plutonium production reactors, but as of the end of 2002 had not yet been permitted to take measurements

[53] See DOE, *FY 2004 Detailed Budget Justifications—Defense Nuclear Nonproliferation*, op. cit., p. 672.

there as specified by the plutonium production reactor agreement.[54])

Nuclear weapons and materials subject to monitoring: rate of progress. As noted earlier, there are no current plans for monitoring or declarations on warhead stockpiles. For material stockpiles, the rate of increase in the amounts of materials subject to monitoring has been painfully slow. As just noted, 50 tons 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; similarly, U.S. government experts hope and expect that monitoring for the plutonium at the production reactors will begin to be fully implemented. Over the longer term, monitoring of plutonium being burned as fuel in the plutonium disposition effort would begin – though most of the 34 tons covered by the existing disposition agreement would come from the 50 tons to be stored in Mayak, so these amounts cannot be added. No date for completing monitoring arrangements for warheads and materials has been established.

Ending Production

Stopping production of fissile material: fraction accomplished. The metric here is very simple: the reduction in the rate of fissile material production resulting from U.S. sponsored programs. So far, U.S.-funded programs have not affected this production rate. Russian production of HEU for weapons ended, and most of Russia's plutonium production reactors were shut, before cooperative threat reductions programs began. The plutonium production rate at the last three production reactors has been reduced because of reductions in their permitted peak power imposed by Russia's nuclear safety regulatory agency, but this was not the result of U.S. programs intended to reduce plutonium production. U.S.-funded efforts to end production of plutonium at these last three reactors have shifted from focusing on shutting these reactors by providing alternative heat and power sources, to converting these reactors to a new fuel cycle that would no longer produce weapons plutonium, and back to shutting them down. As a result, though the United States and Russia agreed in 1994 that these reactors would be shut by the year 2000, they are still operating, and are expected to operate through 2008–2011.[55] At the same time, the Bush administration has dropped Clinton-era efforts to negotiate an end to Russia's continuing separation of civilian weapons-usable plutonium. As a result, tons of additional weapons-usable separated plutonium continue to accumulate in Russia.

Stopping production of fissile material: rate of progress. Because of the shifts in approach just mentioned, a variety of U.S.-Russian disagreements, and interagency disputes within the United States, progress in this effort has been meager in recent years. Plutonium production is expected to continue at its current rate until the reactors are finally shut down in 2008–2011. Here, too, we believe a substantial acceleration of the effort is needed, and would be possible with sustained high-level attention to overcoming the obstacles.

Reducing Nuclear Stockpiles

Dismantling warheads: fraction accomplished. Although Nunn-Lugar is often thought of as a weapons dismantlement effort, the fact is that the United States has never paid for the dismantlement of a single Russian nuclear warhead – because Russia and the United States have never been able to agree on the kind of monitoring measures the United States would require to ensure that the dismantlements it was paying for were really occurring. Nunn-Lugar routinely pay for the dismantlement of nuclear missiles, bombers, and submarines, but not for dismantlement of the warheads themselves.

Nevertheless, Russia has dismantled thousands of nuclear warheads since the collapse of the former Soviet Union. Under the Department of Defense's

[54] Interview with State Department official, November 2002.

[55] See Matthew Bunn, "Plutonium Production Reactor Shutdown," *Controlling Nuclear Warheads and Materials* (available at http://www.nti.org/e_research/cnwm/ending/plutonium.asp as of March 12, 2003). The current planned shutdown dates are in See DOE, *FY 2004 Detailed Budget Justifications—Defense Nuclear Nonproliferation*, op. cit., p. 713.

nuclear warhead transportation program, by April 2002 the United States has provided assistance for shipping some 2,000–3,000 warheads to dismantlement plants or central storage facilities, indirectly contributing to dismantlement.[56]

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 2002, 171 tons of HEU had been blended down under this agreement, the equivalent of more than 8,500 nuclear warheads.[57] One might argue that counting this in the assessment of both the number of warheads dismantled with U.S. help and the amount of HEU destroyed with U.S. help amounts to double counting – but one could also argue that this purchase agreement has a double effect, providing an incentive both for weapon dismantlement and for destruction of HEU.

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 (whose dismantlement 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 32,000 warheads in 1993, when the HEU Purchase Agreement began, and has since reduced this figure to some 20,000.[58] 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 more than a quarter of the total stockpile of nuclear warheads that Russia had when the agreement began.

Dismantling warheads: rate of progress. Today, some 30 tons a year of HEU is being blended down under the HEU Purchase Agreement, representing the equivalent of some 1,500 warheads per year, roughly an additional 5% each year of the warheads Russia had when the HEU Purchase Agreement began. The HEU Purchase Agreement is currently scheduled to end in 2013. As there is no program in place to directly fund Russian warhead dismantlement, there is no planned completion date for such an effort.

Reducing HEU stockpiles: fraction accomplished. As just noted, by the end of 2002, 171 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. This represents some 16% of the over 1,000 tons of weapon-grade HEU equivalent Russia was believed to possess when the HEU deal began.[59]

Reducing HEU stockpiles: rate of progress. As already described, an additional 30 tons of HEU is currently being destroyed each year, representing roughly an additional 3% of the original Russian HEU stockpile. The program is currently

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[56] Defense Threat Reduction Agency, "Nuclear Weapons Transportation," no date (available at http://www.dtra.mil/ctr/project/projrus/ctr_transportation.html as of January 21, 2003).

[57] U.S. Enrichment Corporation (USEC), "Status Report: U.S.-Russian Megawatts to Megatons Program" (Bethesda, Md.: USEC, September 2002; available at http://www.usec.com/v2001_02/HTML/Megatons_status.asp as of January 21, 2003). USEC, using the IAEA "significant quantity" number of 25 kilograms of HEU per warhead, describes the 171 tons as the equivalent of 6,856 warheads; a lower figure of 20 kilograms per warhead would lead to an estimate that this represents more than 8,500 warheads.

[58] See, for example, Robert S. Norris and William M. Arkin, "NRDC Nuclear Notebook: Global Nuclear Stockpiles, 1945–2000," *Bulletin of the Atomic Scientists* 56, no. 2 (March/April 2000; available at http://www.thebulletin.org/issues/nukenotes/ma00nukenote.html as of January 21, 2003).

[59] For discussion, see David Albright, Frans Berkhout, and William Walker, *Plutonium and Highly Enriched Uranium 1996: World Inventories, Capabilities, and Policies* (Oxford: Oxford University Press for the Stockholm International Peace Research Institute, 1997). Their central estimate of the Russian inventory of HEU prior to the beginning of blend-down is 1,050 metric tons of weapon-grade equivalent material; this is subject to an uncertainty of as much as plus or minus 300 tons.

scheduled to end in 2013, after 500 tons – just under half of the original stockpile – has been blended. 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.[60] If the HEU Purchase Agreement were simply extended to cover an additional 300 tons of material at the current blend-down rate, the effort would not be completed until 2023.

Reducing plutonium stockpiles: fraction accomplished. As noted earlier, international cooperative efforts to reduce stockpiles of excess weapons plutonium have so far focused on laying the groundwork: no substantial amounts of excess weapons plutonium have yet been used as reactor fuel or otherwise transformed into forms unsuitable for weapons use. Hence, the fraction accomplished to date is zero.

Reducing plutonium stockpiles: rate of progress. To date, the annual rate of progress in reducing excess plutonium stockpiles is also zero. Current plans are to begin destroying approximately two tons per year of Russian excess weapons plutonium in approximately 2008, though that schedule is likely to slip somewhat.[61] Once a rate of two tons a year has been achieved, it is to be increased to four tons per year. Russia will carry out disposition of approximately 38 tons of separated plutonium under the agreement, including 34 tons of excess weapons plutonium and 4 tons of reactor-grade plutonium with which it will be blended, to maintain the confidentiality of the precise isotopic mix in Russia's weapons plutonium. If operations in fact began in 2008, and the four ton per year rate were achieved quickly, disposition of the material covered by this initial agreement could be completed in 2018–2020; if the program remained at two tons per year, disposition of this material would not be completed until 2027, even if it began in 2008. The 38 tons of material covered in this agreement, however, represents less than one-quarter of Russia's total stockpile of roughly 170 tons of separated plutonium (counting both weapons plutonium and weapons-usable civil plutonium).[62] 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.[63] 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 to 2040 (or beyond 2070 at two tons per year).

Summary: How Much of the Job is Done?

Figure 5.6 summarizes what fraction of the job has been accomplished, when judged by the metrics

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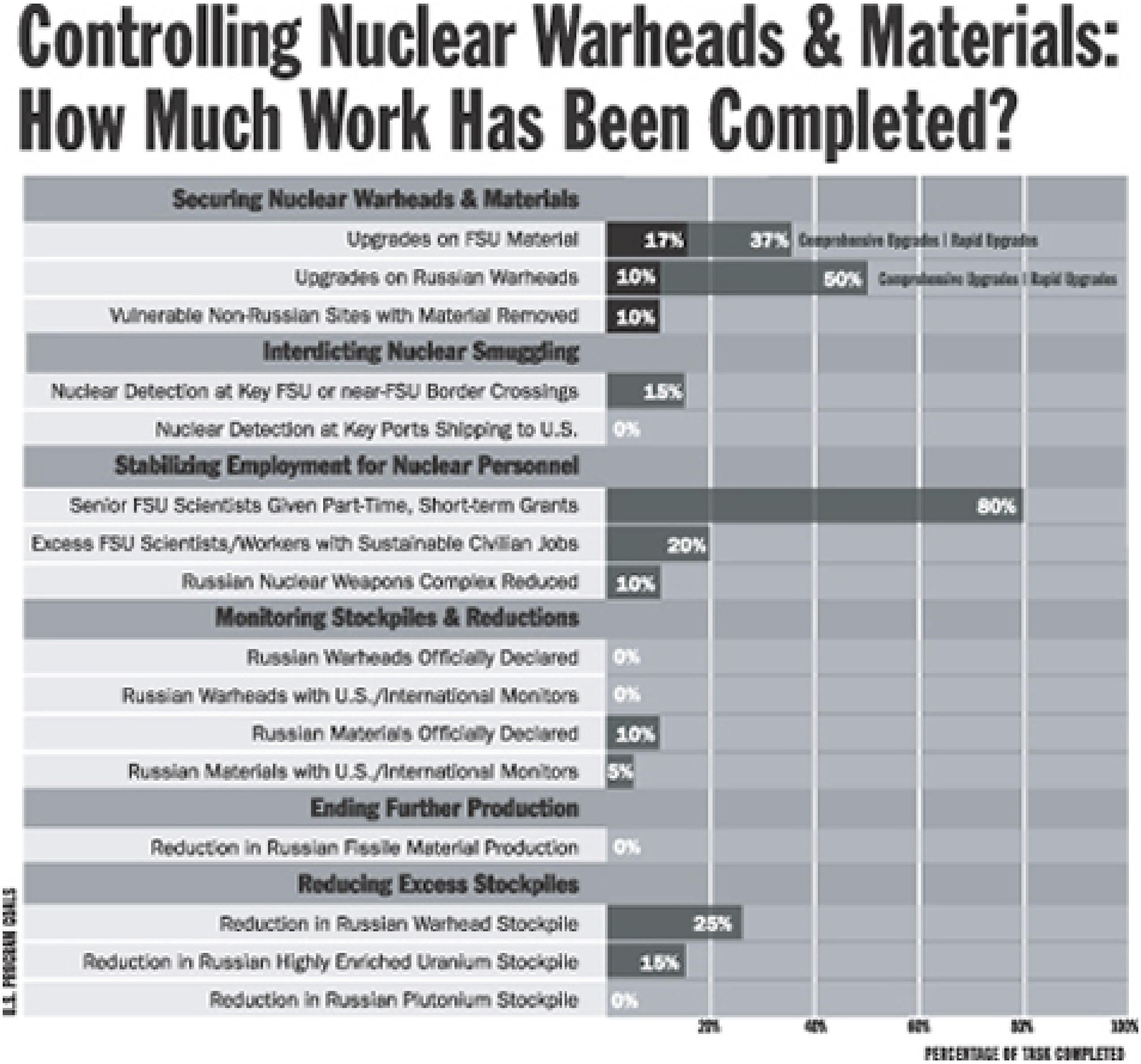
[60] For discussion, see "Reducing HEU Stockpiles – An Accelerated Blend-Down Initiative," p. 194.

[61] These dates and rates are specified in the *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* (signed September 2000; available at http://www.nti.org/db/nisprofs/russia/fulltext/plutdisp/pudispft.pdf as of January 21, 2003). For discussion, see "Russian Plutonium Disposition," *Controlling Nuclear Warheads and Materials* (available at http://www.nti.org/e_research/cnwm/reducing/rpdispose.asp as of March 12, 2003).

[62] Albright, Berkhout, and Walker, *Plutonium and Highly Enriched Uranium 1996*, op. cit., estimate 131 tons of military plutonium (with an uncertainty of plus or minus 25 tons) as of the end of 1993; since then, roughly 6–8 tons of additional weapons plutonium has been produced in Russia's remaining weapons plutonium production reactors. Russia has also declared that it has 32.5 tons of separated civilian plutonium, bringing the total to the range of 170 tons. See International Atomic Energy Agency (IAEA), "Communication Received from Certain Member States Concerning Their Policies Regarding the Management of Plutonium," INFCIRC/549/Add.9/4 (Vienna, Austria: IAEA, September 11, 2002; available at http://www.iaea.org/worldatom/Documents/Infcircs/2002/infcirc549a9-4.pdf as of January 21, 2003).

[63] The plutonium production reactors continue to produce in the range of a ton 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.

Figure 5.6



described above for each of the six categories of effort. All of the ratings have been rounded to the nearest 5%, which still exaggerates, in many cases, the degree of precision in these estimates (exact figures on rapid and comprehensive security upgrades for nuclear material in the former Soviet Union are actually provided, because the Department of Energy has actually published such numbers). Overall, it is clear that while much has been accomplished in these efforts, across a broad range of metrics, much less than half of the job has yet been done, after more than a decade of threat reduction efforts. In most cases, the rate of progress even after the September 11 attacks, if continued on its present course, would still mean that it would be many years before these urgent security threats to U.S., Russian, and world security were fully addressed. For most of the metrics, no planned completion date is available – because the relevant programs have not prepared a strategic plan laying out the total picture of what they plan to accomplish, and when they plan to complete their missions.

In short, an enormous gap remains between the urgency of the threat and the scope and pace of

U.S. efforts to address it. If nuclear weapons, materials, and expertise are to be prevented from falling into the hands of terrorist groups or hostile states, a substantially accelerated effort will be needed, focused on addressing the highest security priorities first.