REPORT

THE U.S. HIGHLY ENRICHED URANIUM DECLARATION: TRANSPARENCY DEFERRED BUT NOT DENIED

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In February 2006, the Department of Energy (DOE) released its historical account of U.S. production and disposition of highly enriched uranium (HEU) through 1996. The report was unclassified and had been completed in 2001, but it required five years of petitions and appeals under the Freedom of Information Act (FOIA) before the Bush administration was forced to release it. According to the report, in 1996 the United States had a stockpile of 741 metric tons (MT) of HEU with an average enrichment of 84 percent. Of that stockpile, 178 MT of HEU with an average enrichment of 62 percent had been declared excess for military purposes. In 2005 and 2006, an additional 70 MT was declared excess and 138 MT was put into a reserve for future use as naval reactor fuel. An estimated 5 MT of HEU was lost due to ''normal operating losses,'' and there was a residual discrepancy of about 3 MT between the number obtained by subtracting cumulative disposition from cumulative production and the actual 1996 stockpile. This article discusses the value of this information and provides insights about the feasibility of declaring additional U.S. weapons HEU excess and the ultimate limits of nuclear disarmament verification.

KEYWORDS: Highly enriched uranium; secrecy; Department of Energy; Freedom of Information Act

In February 2006, the U.S. Department of Energy (DOE) finally released its report, *Highly Enriched Uranium [HEU]: Striking a Balance—A Historical Report on the United States Highly Enriched Uranium Production, Acquisition, and Utilization Activities from 1945 through September 30, 1996* (henceforth, the *HEU Report*). This report is interesting both in its own right and also as a case study in the gyrations of the secrecy culture in the U.S. government. In this article, we discuss first the decade-long debate over government secrecy that preceded the DOE's decision to release it, then what can be learned from this 164-page landmark document, and finally, the value of nuclear transparency and the report's relevance to some of the central questions of nuclear arms control and disarmament.

Background

The *HEU Report* emerged from the ''Openness Initiative'' that was launched by Secretary of Energy Hazel R. O'Leary in December 1993. The Openness Initiative was a response to the

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changed security environment associated with the end of the Cold War, the demands of concerned members of the public, and internal agency imperatives to modernize an anachronistic security policy. Openness meant the creation of new channels of communication and new public information for assessing DOE performance, past and present.

''Classification policy must reflect current worldwide realities (technical, military, economic, and political),'' O'Leary's reformed DOE declared in 1994. ''The balance of risks and benefits has changed, reflecting widespread diffusion of technology, altered military and political relationships such as the breakup of the Soviet Union, and heightened concern about proliferation by Iraq, North Korea, and others.''[1]

While the Openness Initiative was largely characterized by declassification of numerous categories of nuclear information, there was more to it than that. In fact, the ensuing classification policy review also led to *increased* classification for certain other categories of information, in accordance with the discriminating approach often described as ''high fences around narrow areas.''

In 1996, the DOE published a history of U.S. plutonium production, *Plutonium: The First 50 Years, United States Plutonium Production, Acquisition and Utilization from 1944 through 1994,* including official disclosure of the total plutonium inventory.[2] The DOE said: ''As a result of this declassification, the American public will have information that is important in consideration of the proper management and ultimate disposition of the plutonium stockpile.''[3]

The DOE also announced that it would prepare a companion study on HEU: ''Since the Department has received numerous inquiries from the public, a similar report will be written about the production, use, disposition, and inventories of highly enriched uranium covering the last 50 years and will be released in about 1 year.''[4]

The Struggle over the Report's Release

But the promised delivery date was repeatedly postponed. As late as 2005, despite continuing pressure from public interest groups, members of Congress, and former department officials, DOE formally refused to release any portion of the document. In 2006, however, facing a Freedom of Information Act (FOIA) challenge, the *HEU Report* was finally published with only limited redactions.

The decade-long struggle for disclosure of the document reflects the DOE's ambivalence over public disclosure of nuclear information, the reflexive secrecy that has characterized the nuclear weapons complex throughout its history, and shifting conceptions within government of the requirements of national security policy.

The DOE's return to its traditional secrecy was accelerated by a series of embarrassments during the late 1990s. There were highly publicized losses of classified materials at its weapons design laboratories, allegations of Chinese nuclear espionage, the Wen Ho Lee controversy, and more.[5]

Later, in the aftermath of the September 11, 2001 terrorist attacks, the Los Alamos National Laboratory (LANL) rescinded online public access to most of its unclassified public reports.[6] In an often indiscriminate rush to secrecy, LANL even removed a web page

containing the periodic table of the elements and placed it behind a password-protected portal. It was not an auspicious time to set a new standard for nuclear transparency.

Yet the successful outcome of the dispute over the *HEU Report* underscores the virtue of persistence in confronting official secrecy and reaffirms the continuing potency of the FOIA as a lever for opening sealed government files.

The initial delays in producing the *HEU Report* were not due to a resistance to openness, however, but rather to the difficulty of the task itself. The record of HEU production was more fragmentary and complex than anticipated. As of January 1997, the HEU report had been ''delayed by more than 6 months due to difficulties with identifying, accessing, and analyzing historical production and transaction data, which have proved more difficult than was the case with the earlier report on plutonium.''[7] Nevertheless, DOE reaffirmed its commitment to publication of the *HEU Report*. ''This report will provide assistance to worldwide nonproliferation efforts by revealing where United States highly enriched uranium resides in the United States as well as in other nations. It will also assist regulators in environmental, health, and safety matters at domestic sites where this material is stored or buried,'' DOE said in 1997.[8]

Later that year, however, Secretary O'Leary left the DOE, and the Openness Initiative that had been so visibly identified with her tenure began to lose momentum. The *HEU Report* was only completed and formally declassified in January 2001, the transition month from the Clinton to the Bush administration. In anticipation of ''media interest,'' an internal DOE memo said, ''options for release of the report are being developed.''[9] By 2002, however, DOE had settled back into the pre-O'Leary policy of non-disclosure, whose implementation mantra could have been ''deny, delay, and obfuscate.'' This policy was completely compatible with the information policy of the new Bush administration.

Because the *HEU Report* had already been declassified, however, it could no longer be withheld on national security grounds. DOE officials therefore strained to find another basis to block public access. ''The requested document is a draft record that reflects the tentative views of the authors,'' ventured DOE FOIA Director Abel Lopez in an April 10, 2002 letter. ''The opinions contained in the document are recommendatory. . .and exempt from disclosure.''[10]

''That's nonsense,'' said Roger Heusser, who, prior to retiring, had been director of DOE's Office of Nuclear and National Security Information, responsible for DOE classification and declassification policy. ''The document is an historical accounting of information rather than recommendations,'' said Heusser at the time. ''I am quite familiar with the document,'' he wrote in an appeal to DOE security officials. In fact, ''I declassified it.''[11] Nevertheless, Heusser's own request for a copy of the document was also denied, as were requests from public interest groups, arms control specialists, and the National Academy of Sciences.

The intervening events of September 11, 2001 naturally led to a reassessment of security policies government-wide. The threat of terrorism became a new rationale for DOE to withhold the HEU study. ''The report contains unclassified but sensitive security information that terrorists could use as a road map to the locations of DOE fissile nuclear materials and by that provides targeting information for potential malevolent acts,'' wrote Joseph S. Mahaley, director of the DOE Office of Security, in a June 2003 letter

to Sen. Gordon H. Smith (Republican of Oregon) explaining the department's continuing refusal to release the document.[12]

In this same letter, however, Mahaley told the senator that, "I have recently directed that a revision of the report be prepared that will remove the sensitive portions that caused the original document to be withheld from the public." One would have thought that the stage was finally set for release of a revised version of the *HEU Report*. But one would have been mistaken. In 2005, disclosure of the *HEU Report* was again denied in its entirety.

In a January 2005 letter, Marshall O. Combs, the new DOE security director, stated that the revised report was exempt from disclosure because it is an "internal" document that is also "pre-decisional." Furthermore, and despite the revisions directed by Mahaley, the terrorist threat precluded release, he said. "Disclosure of the information would permit terrorists to assess the nation's vulnerability and target locations to damage the nation's critical infrastructure." Combs concluded that no portion of the document could be released.[13]

Fortunately, one of the strengths of the FOIA is that it provides an appeal mechanism for reconsideration of such denials. In this case, the refusal to disclose a single word of the HEU history was so sweeping and so obviously inappropriate that an appeal filed by the Federation of American Scientists received a largely favorable ruling from the DOE Office of Hearings and Appeals. Portions of the denial were sustained by the appeals panel. "Information revealing the location and quantity of fissile material can be properly withheld" for security reasons, the panel said. However, the report also "contains a great deal of purely factual information, such as facts, figures, photographs, and historical narrative. . . . A significant amount of the withheld factual information contained in the Report could be released without revealing the location or quantities of fissile materials." The panel told the Office of Security that it "cannot continue to withhold this information under the cited reasoning" and must either release it or provide a new rationale for withholding it.[14]

Despite the appeals panel ruling, the DOE Office of Security did continue to withhold the information for nearly a year but then, at long last, released the 173-page report in February 2006 with only minor redactions.[15]

What Does the Report Tell Us?

Ironically, much of the "bottom-line" information in the *HEU Report*—including the data on HEU stocks at different DOE facilities that the Bush administration found so threatening—had already been released in a 1996 DOE "openness" press conference.[16] However, the detailed information in the *HEU Report* adds considerable value. Here, we summarize some of this information.

Total Production, Use, and Export of HEU

Table 1 shows the amounts of uranium-235 (U-235) in HEU that the United States had produced, consumed, and still retained as of September 30, 1996. The definition of HEU is

uranium enriched to 20 percent or greater. In the report, the quantities are often given both in terms of total quantity of HEU and quantity of contained U-235. In terms of enrichment work, the latter measure is the most appropriate. It takes 215 kg separative work units (SWUs) to make 93.5 percent enriched weapons-grade uranium containing 1 kg of U-235. It takes 90 percent as much to make 20 percent enriched uranium containing the same amount of U-235.[17]

The U.S.-produced HEU contained about 860 MT of U-235. However, some of that HEU was re-fed into the enrichment plants to produce more HEU, and a small amount was blended down to lower enrichment. The net amount of HEU produced therefore contained about 745 MT of U-235. An additional 4.9 MT was acquired from other countries.[18]

About 32 MT of this U-235 was used in nuclear explosives that were tested or was consumed in naval-reactor fuel. These two categories are combined in the report—perhaps to conceal the average amount of HEU in U.S. nuclear weapons.

About 56 MT was consumed in the plutonium and tritium production reactors at the Savannah River Plant in Aiken, South Carolina, and in research reactors.[19] One and a half MT was blended down to low-enriched uranium (LEU) containing less than 20 percent U-235.

About 32 MT of U-235 in U.S. HEU—enough to make more than 1,000 nuclear weapons—was shipped abroad for use in research reactor fuel or British naval reactor fuel and remains abroad or was fissioned or blended down there to LEU. The *HEU Report* combines these exports with unspecified ''classified transactions''—most likely to conceal the amount that was transferred to the United Kingdom (UK). Data are available, however, from the Nuclear Regulatory Commission (NRC) denoting the amount of U-235 that was exported for research reactor fuel that had not been returned as of 1996: about 11.7 MT.[20] In addition, in its own HEU declaration, the United Kingdom has made it known that it produced and acquired as of March 31, 2002 a total 26.36 MT of HEU for military

TABLE 1
Stocks of U.S. HEU and cumulative production, acquisition, and consumption (metric tons, as of September 30, 1996)

	Total HEU	Contained U-235	Average enrichment
Cumulative production less refeed at enrichment plants		745.3	
Acquired from foreign countries		4.9	
Consumed in nuclear explosions and naval reactors		31.9	
Consumed in other nuclear reactors		56.2	
Blended down to LEU		−1.5	
''Normal operating losses''		−4.9	
''Inventory difference''		−3.2	
Transfers to foreign countries and classified transactions		−32.2	
1996 stockpile	740.7	620.3	83.7%

purposes.[21] UK domestic production has been estimated as equivalent to 4.4 MT of weapons-grade uranium.[22] If all the HEU shipped by the United States to the United Kingdom were weapons grade, the amount of U-235 in the sum of the U.S. U-235 that remains abroad in research reactor fuel and in the UK military stockpile accounts completely for the 32 MT shipped abroad. There is therefore little room left for substantial "classified transactions" other than to the United Kingdom.

Finally, 5 MT of U-235 in HEU disappeared due to "normal operating losses" in various waste streams, and there is a 3-ton total "inventory difference," that is, a discrepancy between the amount of U-235 in HEU calculated from the production and disposition data that should have been in the 1996 stockpile and what was actually there. The net result is that, in 1996, the United States still had 620.3 MT of U-235 in HEU with an average enrichment of 83.7 percent.

Distribution of HEU Geographically and by Use

As shown in Table 2, the *HEU Report* divides the U.S. stockpile into two categories: "required" and "surplus." Almost all of the material that is described as required is for weapons and naval reactor fuel, and the average enrichment is about 90 percent. The material declared surplus averages 62 percent enriched and includes 19.3 MT of U-235 in spent naval, production, and research reactor spent fuel.

In 2005, Secretary of Energy Samuel Bodman declared an additional 40 MT of HEU excess for military use and, within the reserve of material that would remain available for military use, designated 160 MT as a reserve for future use in naval reactor fuel. Of the

TABLE 2
Stocks of U.S. HEU (metric tons, as of Sept. 30, 1996)

	HEU	Contained U-235	Average enrichment
REQUIRED	*562.9*	*510.8*	*90.7%*
For weapons and naval reactor fuel Oak Ridge Y-12 Plant, Pantex Plant, and Department of Defense (i.e. in bombs and naval fuel)	548.8	498.3	90.1%
Idaho National Engineering Laboratory	5.0	4.0	
Rocky Flats Environmental Technology Site	3.8	3.6	
Los Alamos National Laboratory	2.9	2.7	
Sandia National Laboratories	0.5	0.5	
Other sites	1.9	1.7	
SURPLUS	*177.8*	*109.5*	*62%*
Y-12, Pantex, and DOD	102.8	59.1	57%
Idaho National Engineering Laboratory (mostly spent naval reactor fuel)	22.4	15.3	68%
Savannah River Site (mostly spent and unirradiated fuel)	22.2	14.5	65%
Portsmouth Gaseous Diffusion Plant (mostly uranium hexafluoride)	21.7	14.1	65%
Other DOE sites	8.7	6.4	74%

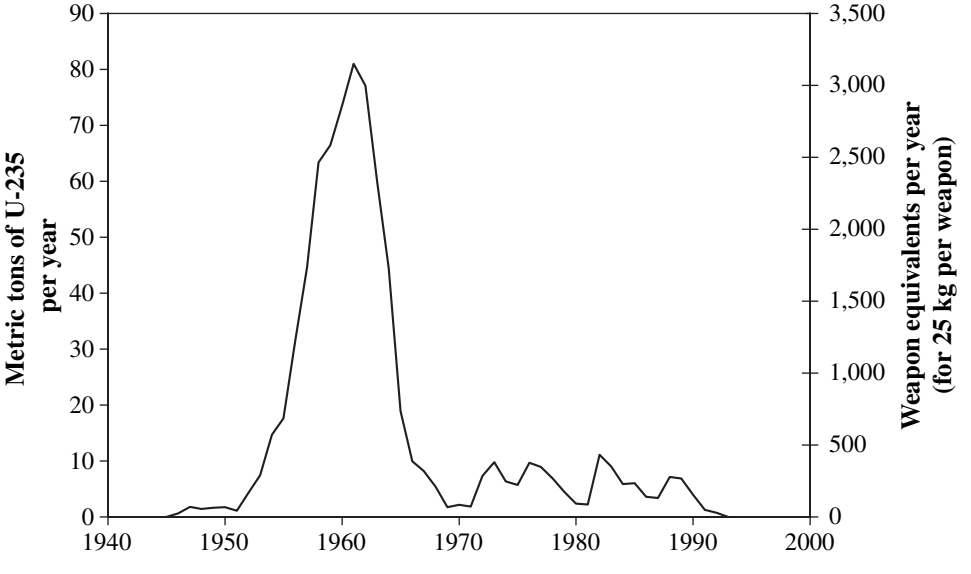
40 MT declared excess, 20 MT will be reserved for future use in HEU-fueled space and research reactors, and 20 MT will be blended down to low enrichment for commercial power reactor fuel. Subsequently, the Navy rejected 32 MT of the 160 tons as unsuitable for its use. That material is to be blended down as well. The Navy also reclaimed for its use 10 MT of the material that had been declared excess in 1978.[23]

History of Production

Figure 1 shows the history of U.S. production of uranium enriched to 90 percent or more. The level was 1–2 MT a year until 1951, when the shock of the first Soviet nuclear test in 1949 resulted in the United States launching a crash program to produce nuclear weapons as fast as it could. During the Eisenhower administration, the production rate climbed steeply until, in 1961, the first year of the Kennedy administration, it peaked at 86 MT. During that year, the United States manufactured more than 5,000 warheads (warhead production peaked in 1960 at more than 7,000 annually).[24]

President Lyndon Johnson terminated U.S. production of HEU for weapons in 1964. By the end of that year, the United States had produced 580 MT of "weapons-grade" HEU enriched to 90 percent or more. Production of HEU at the Oak Ridge Gaseous Diffusion Plant (GDP) ended in 1964, and the Portsmouth GDP was shifted to the production of uranium enriched to more than 96 percent (97 percent average) U-235 for U.S. naval reactors.[25] A total of 164 MT of this very highly enriched naval reactor-grade uranium was produced between 1962 and 1992 for an estimated 600–750 reactor cores.[26] The average

FIGURE 1
History of Net Production of Weapons-Grade Uranium by the United States



amount of HEU per core during this period was therefore about 250 kg. Core inventories increased, however, as the power of the reactors and the lifetimes of the cores increased.

The United States stopped producing HEU altogether in 1992. Since the nuclear navy had not amassed a large stockpile of 97 percent enriched uranium, in the future, it will use the typically 93–94 percent enriched weapons-grade uranium mined from excess Cold War weapons. According to Energy Secretary Bodman, the 160 MT of excess weapons uranium that was designated for naval reactor use would "have the added benefit of postponing the need for construction of a new uranium high-enrichment facility for at least 50 years."[27] At a consumption rate currently estimated as 2 MT per year or less, 160 MT would last at least 80 years.[28]

The Value of Nuclear Transparency

The value of nuclear transparency may not be self-evident. Certainly those government officials who obstructed the release of the *HEU Report* for nearly a decade were not convinced that any compelling reason dictated its public disclosure. And, in a time when government agencies are removing public access to the most mundane information about public infrastructure and government operations, some may fairly wonder whether detailed information about nuclear stockpiles and their locations should be publicized. Yet there is both a principled and a practical case to be made for nuclear transparency.

In principle, as the DOE stated in the first page of the *HEU Report,* "openness is essential to public accountability and trust." For the DOE, this understanding is the fruit of painful experience in confronting extensive waste and contamination issues at its nuclear weapons facilities. To the extent that government operations depend upon public confidence, secrecy can create more problems than it solves.

More concretely, the DOE hoped that the release of HEU production data would "facilitate discussions of HEU storage, safety, and security with stakeholders, [and] encourage other nations to declassify and release similar data."[29] But do public "stakeholders" want to know details of HEU inventories? Are members of the public even capable of contributing to nuclear security policy?

The answer, simply, is "yes." Although there is a tendency for long-term government insiders to presume that outsiders have no conceivable role in developing or overseeing nuclear policy, that presumption is unwarranted and routinely refuted.

In one remarkable recent case, for example, the NRC was persuaded by a public interest group to reverse its post-9/11 adoption of secrecy regarding HEU exports to foreign research reactors. The Nuclear Control Institute (NCI) argued successfully, by pointing to its own record of past interventions in such licensing decisions, that making data on the quantities of HEU involved in such exports available for public comment had allowed it to point out when "an applicant had requested an amount of HEU exceeding its documented need [thereby avoiding] the accumulation of surplus HEU by the applicant."[30] Thus, far from compromising national security, in those cases, openness had actually enhanced it. The NRC agreed and announced that, in the future, "absent an NRC determination of a compelling reason for nondisclosure. . .the NRC intends to disclose

quantity information for enriched uranium above 6 percent U-235, mixed [plutonium-uranium] oxide materials, and certain other radionuclides.''[31]

Needless to say, there are limits to what information can or should be publicly disclosed. Thus, for example, in the same letter to the Nuclear Control Institute in which he announced that the Nuclear Regulatory Commission would no longer classify the quantities of HEU that it was allowing to be exported, NRC Chairman Dale Klein added that ''the NRC will continue to withhold information on projected or actual shipment schedules. . .mode of transport, storage arrangements, or any other related logistical information [that] could be useful to a potential adversary.''[32] Such limits were clearly observed by the authors of the *HEU Report*, which explicitly '''strikes a balance' between openness and the necessity to protect information that needs to remain classified for nonproliferation and national security reasons.''

Public policy regarding the enormously difficult environmental challenges facing many DOE nuclear facilities also is vitally enriched by independent expert assessments, which in turn depend on the availability of reliable government data.[33] Of greatest interest to the readers of the *Nonproliferation Review,* however, is how the disclosure of the production history and size of the U.S. fissile material stockpile data clarifies issues relating to nuclear arms control and disarmament. Below we give some specific examples.

Benefits from Fissile Material Transparency to Nuclear Arms Control and Disarmament[34]

With the two reports, *Plutonium: The First 50 Years* and the *HEU Report,* the U.S. government has laid out a full record of its production of these two key weapons materials; the record of their use and disposition through 1994 and 1996 respectively; and the sizes of its stockpiles as of those dates. This information makes possible judgments about the possibility of declaring more weapon material excess, the relative sizes of the naval reactor and weapon stockpiles of HEU, and the limits of verification of disarmament.

More Weapons Material Could be Declared Excess

The United States has declared 45 MT of separated plutonium and 368 MT of HEU excess for weapons purposes.[35] This leaves about 47 MT of weapons-grade plutonium and (assuming that the Navy used 20 MT between 1996 and 2005) about 350 MT of HEU available for nuclear weapons. Could more material be declared excess?

According to the most reliable nongovernmental estimates, the United States plans to reduce its stockpile to approximately 6,000 warheads by 2012.[36] On average, a U.S. warhead contains very roughly 3 kg of weapons-grade plutonium and 25 kg of weapons-grade uranium.[37] On this basis, 6,000 warheads would contain 18 MT of plutonium and 150 MT of HEU. Even allowing for research and development and working inventories, it would appear that at least 20 more MT of plutonium and 150 more MT of HEU could be declared excess for weapons use. If the United States reduced its total stockpile of warheads closer to the 2,200-warhead limit mandated by the Strategic Offensive Reductions Treaty, the cuts could be much deeper.

Russia's lack of comparable transparency creates a problem, however, for those concerned that U.S. fissile material stockpiles not be reduced to levels much lower than Russia's. Moscow has declared excess 50 MT of plutonium and 500 MT of weapons-grade uranium. It is believed, however, to have larger quantities of fissile material remaining in its weapons stockpile than the United States, although the estimates are quite uncertain.[38]

The Naval Reactor Stockpile Overhang

As noted above, the United States has set aside 138 MT of weapons-grade uranium for future use as naval reactor fuel. This is enough to make about 5,000 warheads. Will Russia keep a similar HEU stockpile? Will the United States, Russia, and other nuclear weapon states in their decisions about the future sizes of their weapon stocks ignore the weapon potential in this HEU? If not, it could become a major impediment to deeper cuts.[39] This problem would be considerably ameliorated if the United States, Russia, and the United Kingdom followed France in shifting their nuclear propulsion reactors to LEU fuel.[40]

The Limits of Verification

In the long term, the United States and the other nations recognized as nuclear weapon states under the Treaty on the Non-Proliferation of Nuclear Weapons are committed to eliminating their nuclear weapons. Verification that this commitment has been fulfilled will require them to place all of their fissile material under international safeguards and to provide the best evidence that they can that none has been secreted away. Only one country, South Africa, has verifiably eliminated its nuclear weapons stockpile in this way, however, and it had only seven weapons. It nevertheless took two years for the International Atomic Energy Agency (IAEA) to satisfy itself that the difference between South Africa's declared HEU stockpile and the production that the IAEA could verify from records and physical evidence was less than 25 kg, that is, one weapon equivalent.[41]

The U.S. stockpile of HEU is much larger, and as a result, so are the uncertainties. As shown in Table 1, cumulative ''normal operating losses'' were estimated in 1996 as 4,900 kg, and the residual ''inventory difference'' between the stockpile calculated from production and disposition records and the actual stockpile was found to be 3,200 kg. The sum of these numbers is about 8,000 kg—enough for about 300 nuclear weapons. It is unlikely that international inspectors would be able to verify the U.S. declaration this well—even with full cooperation. To prevent the possibilities for future international verification from getting even worse, the United States and Russia should preserve all relevant original documents that still exist and also should preserve relevant facilities and materials such as plutonium production reactors and depleted uranium until the evidence related to production that they contain has been fully analyzed and documented by international teams.[42]

Conclusion

The *HEU Report* was inspired by a vision of nuclear transparency that was intended to bolster national and international security and serve as a confidence-building measure, while also setting a new standard for government domestic accountability in nuclear matters: ''The information in this report should aid DOE in discussions with stakeholders related to uranium storage, safety, and security. The publication of this data should encourage other nations to declassify and release similar data. Additionally, this data will assist those responsible for formulating policies with respect to the identification and disposition of excess nuclear materials.''[43]

After a decade-long delay, the report is finally in the public domain, thanks to the Freedom of Information Act and the tenacity of openness advocates inside and outside of government. But the benefits of openness are not self-activating. They can only be brought to fruition by researchers, advocates, and political leaders seizing the opportunity to advance an agenda of nuclear security and accountability. Much work remains to be done if the hopes that inspired the production of the *HEU Report* are to be realized.

NOTES

1. ''Fundamental Review of Dept. of Energy Classification Policy,'' Openness Press Conference Fact Sheets, June 27, 1994. This and other press releases cited below may be found through <www.osti.gov/opennet/index.jsp>.
2. *Plutonium: The First 50 Years: United States Plutonium Production, Acquisition, and Utilization from 1944 through 1994*, Dept. of Energy (DOE), DOE/DP-0127, 1996, <www.osti.gov/opennet/forms.jsp?formurl=document/pu50yrs/pu50y.html>.
3. ''Declassification of the United States Plutonium Inventory and Release of the Report, 'Plutonium: The First 50 Years,''' DOE Press Release, Feb. 6, 1996.
4. ''Openness Fact Sheet Summary,'' DOE Press Release, Feb. 6, 1996.
5. See, for example, *Science at its Best, Security at its Worst*, Report of the President's Foreign Intelligence Advisory Board, June 1999, available at <www.fas.org/sgp/library/pfiab/index.html>.
6. Many of the withdrawn Los Alamos technical reports have since been made available through the Federation of American Scientists (FAS) online, <www.fas.org/sgp/othergov/doe/lanl/index.html>.
7. ''Openness: The Way to Do Business,'' DOE Press Conference Fact Sheets, Jan. 15, 1997.
8. ''Highly Enriched Uranium Report: The First 50 Years—a Commitment,'' DOE Press Release, Jan. 24, 1997.
9. ''Office of Nuclear and National Security Information Weekly Report,'' DOE, Feb. 6, 2001, <www.fas.org/sgp/news/2001/02/doe020601.html>.
10. Letter to Steven Aftergood from Abel Lopez, DirectorFOIA/Privacy Act Division, Office of the Executive Secretariat, DOE, April 10, 2002, <www.fas.org/sgp/news/202/04/doe041002.html>.
11. *Secrecy News*, April 17, 2002, FAS Project on Government Secrecy, <www.fas.org/sgp/news/secrecy/2002/04/041702.html>.
12. Letter to Sen. Gordon H. Smith from Joseph S. Mahaley, director, Office of Security, DOE, June 9, 2003, <www.fas.org/sgp/news/2003/06/doe060903.html>.
13. Letter to Steven Aftergood from Marshall O. Combs, director, Office of Security, DOE, Jan. 24, 2005, <www.fas.org/sgp/news/2005/01/doe012405.pdf>.
14. Decision and Order of the DOE, ruling of the DOE Office of Hearings and Appeals, Case No. TFA-0088, March 7, 2005, <www.fas.org/sgp/news/2005/03/doe heu appeal.pdf>.
15. *Highly Enriched Uranium: Striking A Balance—A Historical Report on the United States Highly Enriched Uranium Production, Acquisition, and Utilization Activities from 1945 Through September 30, 1996*, DOE, Jan. 2001 (Revision 1, redacted for public release), <www.fas.org/sgp/othergov/doe/heu/index.html>

or <http://osti.gov/opennet/reports/RedactedHEUReportDraft.pdf>. Note: The OSTI version is a 58-megabyte file.

16. The information released by DOE may be found on the U.S. government's Opennet Database, <https://www.osti.gov/opennet/press.jsp>. On June 27, 1994, the DOE released the total historical amounts of U.S. HEU production and current inventories at all DOE sites other than the Pantex Plant warhead assembly/disassembly facility at Amarillo, Texas, and on Feb. 6, 1996, the locations and amounts by facility of the 174.3 MT of HEU declared excess.
17. Assuming that the enrichment feed is natural uranium containing 0.711 percent U-235 and that the depleted uranium "tails" contain 0.3 percent U-235.
18. This is 4.3 MT in spent research reactor fuel containing HEU that was originally exported from the U.S. and 0.6 MT in former Soviet HEU imported from Kazakhstan in "Project Sapphire" in 1994.
19. The plutonium production reactors at the Hanford Reservation in Washington State were fueled with natural and 1-percent enriched uranium.
20. David Albright, William Walker, and Frans Berkhout, *Plutonium and Highly Enriched Uranium, 1996: World Inventories, Capabilities, and Policies* (New York: Oxford University Press, 1997), p. 252.
21. *Historical Accounting for UK Defence Highly Enriched Uranium: A Report by the Ministry of Defence on the Role of Historical Accounting for Highly Enriched Uranium for the United Kingdom's Defence Nuclear Programmes*, Ministry of Defence (United Kingdom), March 2006, p. 4, <www.mod.uk/NR/rdonlyres/DDDBEE8B-F36D-457E-B472-C6C2877EE804/0/HistoricalAccountingForDefenceHighlyEnriched Uranium.pdf>.
22. Albright, Walker, and Berkhout, *Plutonium and Highly Enriched Uranium, 1996*, p. 120.
23. "Remarks Prepared for Energy Secretary Sam Bodman, 2005 Carnegie International Nonproliferation Conference," Washington, DC, Nov. 7, 2005, <www.carnegieendowment.org/static/npp/2005 conference/presentations/bodman_remarks.pdf>. On the 32 MT declared unsuitable by the Navy, see Dean Tousley, acting director, DOE Office of Disposition Projects, and Robert George, HEU disposition program manager, "U.S. Highly Enriched Uranium Disposition," presentation at the Nuclear Energy Institute Nuclear Fuel Supply Forum, January 24, 2006, reproduced in the Project on Government Oversight report, *U.S. Nuclear Weapons Complex: Y-12 and Oak Ridge National Laboratory at Risk,* October 16, 2006, Appendix F, <www.pogo.org/p/homeland/ho-061001-Y12.html>. On the Navy's reclaimed 10 MT, see Michael Knapik, "DOE Has Limits on HEU Sales This Decade," *Nuclear Fuels* 30 (January 31, 2005), p. 1.
24. Robert S. Norris and Hans M. Kristensen, "Global Nuclear Stockpiles, 1945–2006," *Bulletin of the Atomic Scientists* 62 (July/Aug. 2006), pp. 64–66, <http://thebulletin.metapress.com/content/c4120650912x74k7/fulltext.pdf>.
25. The third U.S. gaseous diffusion plant, at Paducah, Kentucky, produced slightly enriched (0.9–1.1 percent) enriched uranium, which was fed into the other two (*HEU Report,* p. 27). Today, it is the only one of the three still in operation. It produces uranium enriched to up to 5 percent for light water power reactor fuel.
26. Albright, Walker, and Berkhout, *Plutonium and Highly Enriched Uranium, 1996,* p. 87.
27. "Remarks Prepared for Energy Secretary Sam Bodman," Nov. 7, 2005.
28. Estimate made in Chunyan Ma and Frank von Hippel, "Ending the Production of Highly Enriched Uranium for Naval Reactors," *Nonproliferation Review* 8 (Spring 2001), p. 86, <http://cns.miis.edu/pubs/npr/vol08/81/81mahip.pdf>.
29. *HEU Report*, p. 1.
30. Letter from Alan J. Kuperman and Paul L. Leventhal, Nuclear Control Institute (NCI), to Nils Diaz, then chairman of the Nuclear Regulatory Commission (NRC), Feb. 13, 2006, <www.fas.org/sgp/news/2006/02/nci021306.pdf>.
31. Letter to Alan J. Kuperman, NCI, from Dale E. Klein, chairman, NRC, Aug. 31, 2006, <www.fas.org/sgp/news/2006/09/nrc083106.pdf>.
32. Ibid.
33. See, for example, "Reducing the Risks of Highly Enriched Uranium at the U.S. Department of Energy's Y-12 National Security Complex" by Robert Alvarez, Institute for Policy Studies, Washington, DC, Sept. 20, 2006 (draft).
34. Thoughtful discussion of the feasibility, utility, and limits of nuclear transparency may be found in *Monitoring Nuclear Weapons and Nuclear-Explosive Materials*, Committee on International Security and

Arms Control (Washington, DC: National Academy Press, 2005). More background on past U.S.-Russian exchanges on possible bilateral and trilateral (with the International Atomic Energy Agency) transparency arrangements may be found in Matthew Bunn, Anthony Wier, and John P. Holdren, *Controlling Nuclear Warheads and Materials: A Report Card and Action Plan,* Nuclear Threat Initiative and the Project on Managing the Atom, 2003, <www.nti.org/e_research/cnwm/monitoring/index.asp>.

35. In addition, the United States has declared 7.5 MT of government-owned plutonium in spent fuel excess for its defense needs, International Atomic Energy Agency Information Circular 549/Add.6/1, Oct. 11, 1999.

36. Robert S. Norris and Hans M. Kristensen, ''U.S. Nuclear Reductions,'' *Bulletin of the Atomic Scientists* 60 (Sept./Oct. 2004), p. 70. It is quite possible, however, that, if warhead dismantlement is not given a higher priority in the interim, thousands of additional warheads will still be in the dismantlement queue in 2012.

37. These estimates are obtained by dividing the 66 MT of weapons-grade plutonium and the 650 MT of HEU in the U.S. weapon complex (nuclear weapons, the Y-12 HEU-component production facility, and the Pantex warhead assembly/disassembly facility) by the estimated 24,000 warheads in the U.S. nuclear stockpile in the mid-1980s, Robert S. Norris and Hans M. Kristensen, ''Global Nuclear Stockpiles, 1945–2006.'' During that period, the Reagan administration mounted a program to produce additional weapons-grade plutonium and expressed a concern about limitations on the availability of HEU for weapons, Thomas B. Cochran, William M. Arkin, Robert S. Norris, and Milton M. Hoenig, *U.S. Nuclear Warhead Production* (Cambridge, MA: Ballinger, 1987), p. 92.

38. See for example the estimates in Albright, Walker, and Berkhout, *Plutonium and Highly Enriched Uranium, 1996,* pp. 399, 400.

39. See the discussion in chapter 2 of *Global Fissile Material Report 2006*, International Panel on Fissile Materials, <www.fissilematerials.org>.

40. Chunyan Ma and Frank von Hippel, ''Ending the Production.''

41. Albright, Walker, and Berkhout, *Plutonium and Highly Enriched Uranium, 1996,* p. 378.

42. Steve Fetter, ''Nuclear Archeology: Verifying Declarations of Fissile-Material Production,'' *Science & Global Security* 3 (1993), p. 225.

43. *HEU Report*, p. 5.