Contract No:

This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-08SR22470 with the U.S. Department of Energy.

Disclaimer:

Tracking Surplus Plutonium from Weapons to Disposition

Jeffrey S. Allender[1], Jay D. Beams[2], Kenneth E. Sanders[2], and Leonard W. Myers[3]

[1]Savannah River National Laboratory, Aiken, SC, USA
[2]National Nuclear Security Administration, Washington, DC, USA
[3]Protection Strategies, Inc., Germantown, MD, USA

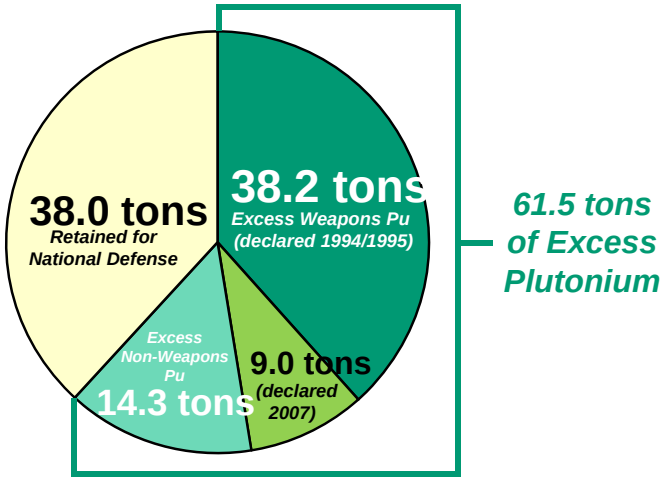
ABSTRACT

Supporting nuclear nonproliferation and global security principles, beginning in 1994 the United States has withdrawn more than 50 metric tons (MT) of government-controlled plutonium from potential use in nuclear weapons. The Department of Energy (DOE), including the National Nuclear Security Administration, established protocols for the tracking of this "excess" and "surplus" plutonium, and for reconciling the current storage and utilization of the plutonium to show that its management is consistent with the withdrawal policies. Programs are underway to ensure the safe and secure disposition of the materials that formed a major part of the weapons stockpile during the Cold War, and growing quantities have been disposed as waste, after which they are not included in traditional nuclear material control and accountability (NMC&A) data systems. A combination of resources is used to perform the reconciliations that form the basis for annual reporting to DOE, to U.S. Department of State, and to international partners including the International Atomic Energy Agency.

BACKGROUND

The U.S. DOE, including the National Nuclear Security Administration (NNSA), is engaged in a program to disposition U.S. surplus weapons-usable plutonium.[1] The U.S. has declared 61.5 MT of plutonium to be excess to potential use in nuclear weapons. Figure 1 shows the distribution of the 99.5 MT of U.S. Government plutonium that was tracked by NMC&A as of September 30, 1994.[2]

Figure 1. "U.S. Government" Plutonium (Based on 1994 Inventory)



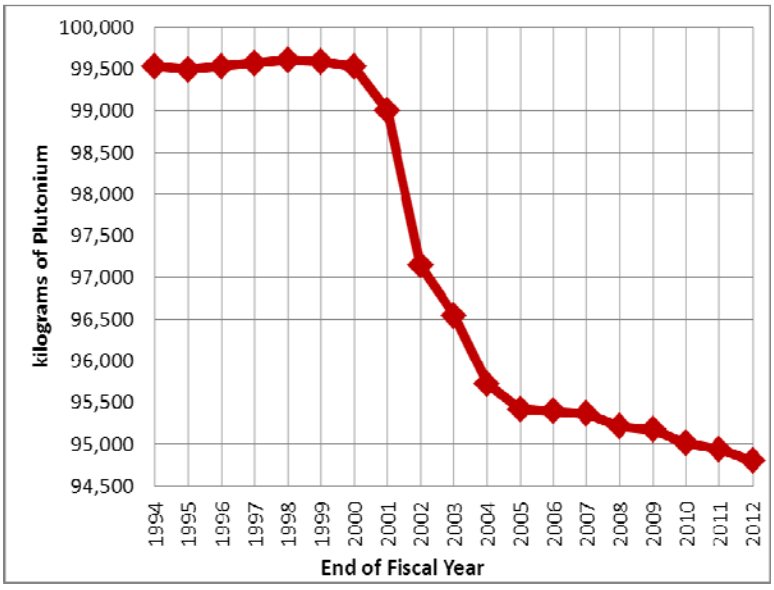
These quantities do not include plutonium that was previously disposed to waste, or plutonium contained within the civilian power-reactor sector. The U.S. Government-controlled plutonium also includes a portion in irradiated fuel. Each portion of the inventory is tracked so that different reports can be prepared for national or international partners.

IDENTIFICATION OF DOE INVENTORIES

The plutonium that was formally removed from potential weapons-program uses is termed "excess," while "surplus" refers to material that is excess to weapons activities and that also has no programmatic use within the DOE.[3] In 2000, DOE and NNSA established a Surplus Fissile Material Baseline (SFMB) process to formally track the plutonium and highly enriched uranium and to account for the excess material against the policy decisions. Each year, the Office of Fissile Materials Disposition within the NNSA Office of Defense Nuclear Nonproliferation reconciles the locations and utilization of plutonium.

The starting point for the tracking is inventory records from the Nuclear Materials Management and Safeguards System (NMMSS), the national data repository for NMC&A and materials utilization.[4] Figure 2 shows the progression of total plutonium that corresponds to the 99.5 MT reported for 1994 through the end of Fiscal Year 2012.

Figure 2. Accountable U.S. Government Plutonium 1994-2012

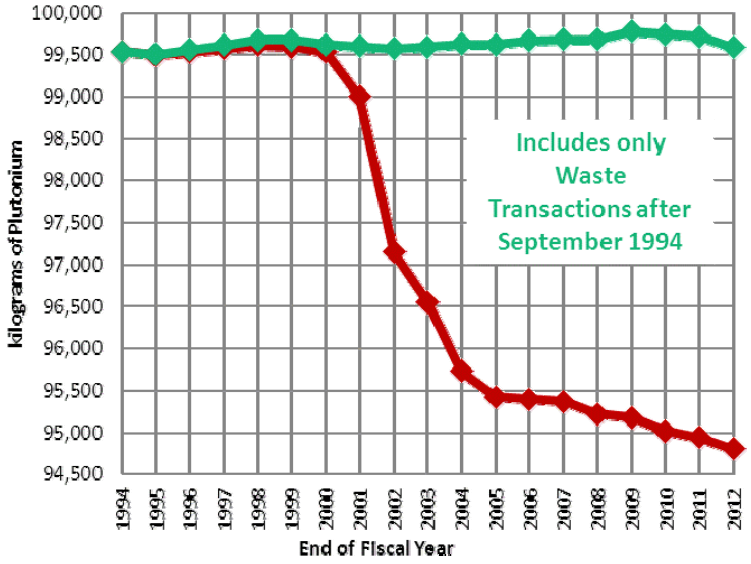


Clearly the tracked inventory has declined. The primary reason for this reduction is plutonium that has been disposed to transuranic and high-level waste systems; these items are not tracked for NMC&A after safeguards is terminated. Removals became sizable beginning in 2001 to support the deinventory of the Rocky Flats Environmental Technology Site (RFETS), and had reached 4.1 MT by the close of 2009.

However, the NMMSS system is structured on a "transactions" model and the removals from active inventories to waste inventories are recorded. The cumulative quantities that have been removed to

different waste accounts are known, e.g., plutonium transferred to a transuranic "waste account" at the Waste Isolation Pilot Plant (WIPP) in New Mexico or to high-level-waste disposal systems at the Savannah River Site. More than a dozen waste accounts are active at DOE sites, including waste materials that are packaged for disposal at another site or a permanent waste repository. Figure 3 shows the tracked totals if these NMMSS waste accounts are included.

Figure 3. U.S. Government Plutonium with Waste Accounts 1994-2012



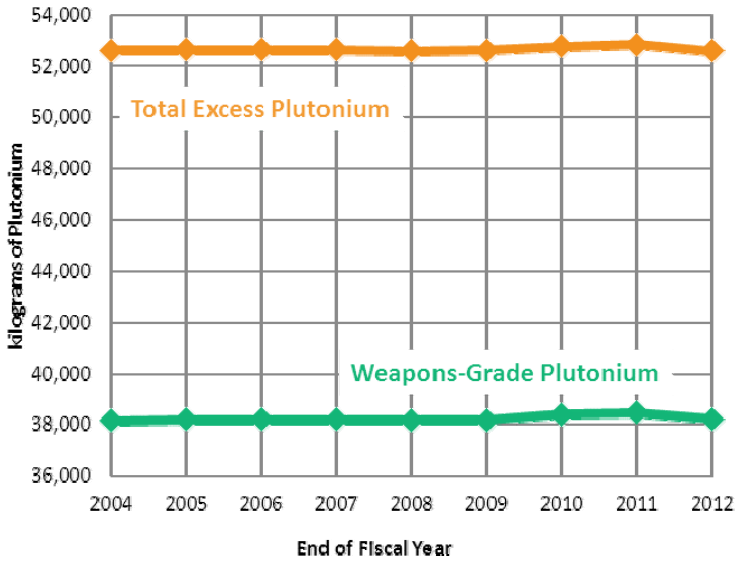
The figures show that the combination of accountable inventories and waste accounting adequately locates the plutonium that was in the end-of-1994 inventory. Minor variations due to radioactive decay, remeasurement, creation in reactors, and receipts from outside DOE can be explored in greater detail, if desired, by examining intrasite and intersite transactions.

UTILIZATION OF DOE INVENTORIES

The NMMSS system only reports on the inventories. Other resources are required to help verify that DOE is managing the Excess plutonium in line with U.S. policy. For plutonium, two key classified reports are prepared annually by the Office of Nuclear Materials Integration: a Pit Master Report and the Nuclear Materials Inventory Assessment (NMIA). The Pit Master tracks weapons components, both deployed and dismantled, by system and quantity. The NMIA consolidates reports from every DOE site on the status of each accountable item. Both indicate whether the components or non-component items are managed as Excess or active National Security, consistent with the SFMB (for plutonium declared Excess in 1994); a similar process for plutonium declared Excess in 2007; or as material received by DOE after 1994 and not included in the formal declarations.

Figure 4 shows the result of verifying the Excess status of the 52.5 MT declared in 1994, including 38.2 MT of weapons-grade plutonium and the 52.5 MT total that includes non-weapons-grade material.

Figure 4. Verifying the Excess Plutonium Inventory



The boundaries between weapons-grade and non-weapons-grade plutonium can vary if items are combined during the process of stabilization and disposition. However, more than 52.5 MT from the end-of-1994 inventory (plus 9 MT declared in 2007) is managed as Excess by DOE.

INTERNATIONAL REPORTING

The United States and other nations agreed to report annually to the International Atomic Energy Agency (IAEA) on their policy and inventories of plutonium, under Information Circular 549: *Guidelines for the Management of Plutonium*.[5] The U.S. agreed to publish:

i. Occasional brief statements explaining its national strategy for nuclear power and the nuclear fuel cycle, and its general plans for managing national holdings of plutonium; and

ii. An annual statement of its holdings of all (separated) plutonium subject to these guidelines; and

iii. An annual statement of its estimate of the plutonium contained in its holdings of spent civil reactor fuel.

The annual reporting is prepared by NNSA's Office of Nonproliferation and International Security, within the Office of Defense Nuclear Nonproliferation. The first annual U.S. statement was submitted to the IAEA based on plutonium inventories at the close of 1996 and 1997.[6] The latest annual addendum was published in October 2012.[7]

The reporting boundaries and categories of interest are specified in the Guidelines, and differ slightly from the categories tracked to support the SFMB process, described above. Tables 1 and 2 shows the inventory summaries that were transmitted in the 2012 Annexes. The 61.5 MT is reported as:

- 49.3 MT is shown as "civil, unirradiated plutonium" in Annex B, lines 3 and 4
- 4.4 MT is identified in the footnotes as already disposed to waste
- 7.7 MT is held in DOE-managed spent fuel, within Annex C, line 3
- 0.1 MT was sent to civilian power reactors, now in Annex C, line 1

Table 1. Information Circular Inventory Annex B

ANNUAL FIGURES FOR HOLDINGS
OF CIVIL UNIRRADIATED PLUTONIUM

(Annex B, International Plutonium Management Guidelines)

National Totals	As of 31 December 2011 [Previous year's figures in brackets] Rounded to 100 kg plutonium Quantities <50 kg reported as such	
1. Unirradiated separated plutonium in product stores at reprocessing plants.	0	[0]
2. Unirradiated separated plutonium in the course of manufacture or fabrication and plutonium contained in unirradiated semi-fabricated or unfinished products at fuel or other fabricating plants or elsewhere.	<0.05 MT	[<0.05 MT]
3. Plutonium contained in unirradiated MOX fuel or other fabricated products at reactor sites or elsewhere.	4.6 MT	[4.6 MT]
4. Unirradiated separated plutonium held elsewhere.	44.7 MT	[49.3 MT]
(i) Plutonium in lines 1-4 belonging to foreign bodies.	0	[0]
(ii) Plutonium in lines 1-4 held in locations in other countries and therefore not included above.	0	[0]
(iii) Plutonium in lines 1-4 which is in international shipment prior to its arrival in the recipient State.	0	[0]

Note:

Lines 3 and 4 together list 49.3 metric tons of separated plutonium that has been declared as excess to national security needs. This, in addition to 7.8 metric tons of the plutonium included on lines 1 and 3 of Annex C and 4.4 metric tons that has been disposed to waste after termination of safeguards post-1998, constitute the total of 61.5 metric tons of government owned plutonium that the United States has declared as excess to national security needs.

Table 2. Information Circular Inventory Annex C

ESTIMATED AMOUNTS OF PLUTONIUM CONTAINED IN SPENT CIVIL REACTOR FUEL

(Annex C, International Plutonium Management Guidelines)

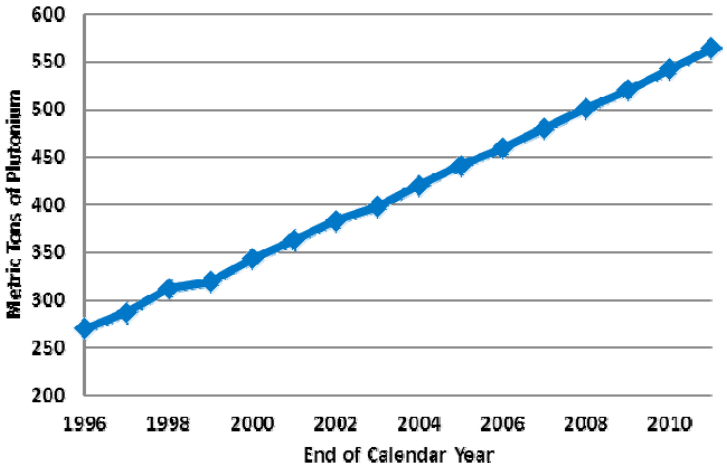
National Totals	As of 31 December 2011 [Previous year's figures in brackets] Rounded to 1000 kg plutonium Quantities <500 kg reported as such	
1. Plutonium contained in spent fuel at civil reactor sites.	564 MT	[542 MT]
2. Plutonium contained in spent fuel at reprocessing plants.	0	[0]
3. Plutonium contained in spent fuel held elsewhere.	12 MT	[12 MT]

Notes:

Line 1 includes 0.1 metric tons of formerly government owned plutonium that was transferred to civil reactors and subsequently irradiated. Line 3 includes 7.7 metric tons of government owned plutonium estimated to be remaining in spent fuel that has been declared as excess to national security needs. These, in addition to 49.3 metric tons of separated plutonium reported in lines 3 and 4 in Annex B and 4.4 metric tons that has been disposed to waste after termination of safeguards post-1998, constitute the total of 61.5 metric tons of government owned plutonium that the United States has declared as excess to national security needs.

Figure 5 shows the progression of estimated plutonium in civilian reactor spent fuel, from the first Information Circular report (showing the end of Calendar Year 1996) through 2011.

Figure 5. Plutonium in U.S. Civilian Reactor Spent Fuel



Annex B is updated periodically, notably in 2004-2006 to report the removal of a small quantity of plutonium that was transferred to France for the fabrication of Lead Test Assemblies (LTAs) for the Mixed Oxide (MOX) fuel program; the return of the LTAs and leftover material to the U.S.; and the transfer of LTAs to the civilian power sector, where the plutonium became part of the spent fuel inventory. In 2007 the declaration of an additional 9 MT of Excess was included, and in 2011 the cumulative quantity of plutonium disposed to waste since 1994 was credited.

HISTORICAL REPORTING

In June 2012, NNSA published a report on U.S. plutonium inventories and their evolution from 1944 through 2009.[8,9] This report updated an analysis published in 1996 in *Plutonium: The First Plutonium: The First 50 Years*[2] and included data from multiple sources. One focus of the 1996 analysis was to track the same end-of-1994 inventories discussed above. Some issues were described for historical accounting, including the tracking of material disposed to waste in the early years. However, the tracking of plutonium management after 1994 is highly consistent with the results described above. Table 3 shows the changes reported for the U.S. Government plutonium for the 1994 and the 2009 inventory dates.

Table 3. U.S. Plutonium: Acquisitions, Removals, and Inventory (MT)

	1994	2009	Change
Receipts			
Production	103.4	103.4	0.0
Research Reactors	0.6	0.7	0.1
From Foreign Countries	5.7	5.8	0.1
From U.S. Industry	1.7	1.8	0.1
Total Receipts	111.4	111.7	0.3
Removals			
Expended in Wartime & Tests	3.4	3.4	0.0
Decay	0.4	0.5	0.1
Fission & Transmutation	1.2	1.3	0.1
Discarded to Waste	3.4	7.8	4.4
To Foreign Countries	0.1	0.2	0.1
To U.S. Industry	0.7	0.8	0.1
Total Removals	9.2	14.0	4.8
Classified & Rounding	0.1	0.1	0.0
Inventory Difference	-2.8	-2.4	0.4
Ending Inventory	99.5	95.4	-4.1

CONCLUSIONS

DOE and NNSA operate a robust suite of applications to track the evolution of plutonium inventories within the U.S., and to verify that the plutonium management is consistent with national nonproliferation policy. Inventories are tracked at the item level using classified systems and are aggregated to support national and international reporting. Existing databases that are commonly associated with NMC&A are also adequate to support Nuclear Materials Management and public accounting.

ACKNOWLEDGEMENTS

The authors also wish to recognize assistance from Brian Horn, U.S. Nuclear Regulatory Commission, and the many sites who provide inventory information; Peter Dessaules, Michael Nightingale, Dunbar Lockwood, and John Murphy of the National Nuclear Security Administration; and interface support by the U.S. Department of State and the Vienna Mission to the IAEA.

REFERENCES

1. U.S. Department of Energy, Second Amended Notice of Intent To Modify the Scope of the Surplus Plutonium Disposition Supplemental Environmental Impact Statement and Conduct Additional Scoping, Federal Register 77, 8, 12 January 2012.

2. U.S. Department of Energy, *Plutonium: The First 50 Years*, DOE/DP-0137, February 1996.

3. U.S. Department of Energy Order: *Nuclear Materials Management*, DOE O 410.2, 17 August 2009.

4. X. Ascanio, J. Beams, and D. Dunsworth, "Inventory Characterization for Planning and Executing Effective and Efficient Consolidation and Disposition Activities," *Proceedings of the Institute of Nuclear Materials Management 51st Annual Meeting*, July 2010.

5. International Atomic Energy Agency, "Communication Received from Certain Member States Concerning Their Policies Regarding the Management of Plutonium," INFCIRC/549, 16 March 1998.

6. International Atomic Energy Agency, Communication Received from Certain Member States Concerning Their Policies Regarding the Management of Plutonium," INFCIRC/549/Add.6/1, 31 March 1998.

7. International Atomic Energy Agency, Communication Received from the United States of America Concerning its Policies Regarding the Management of Plutonium," INFCIRC/549/Add.6/15, 29 October 2012.

8. National Nuclear Security Administration, *The United States Plutonium Balance, 1944-2009: An Update of Plutonium: The First 50 Years*, June 2012.

9. P. Dessaules and L. B. Gunn, "The U.S. Plutonium Balance, 1944-2009," *Proceedings of the Institute of Nuclear Materials Management 53rd Annual Meeting*, July 2012.