PANEL ON PUBLIC AFFAIRS

April 2004

THE MODERN PIT FACILITY (MPF)

No urgency for a MPF.
Address key technical issues before proceeding.

Issue

Congress is considering whether to authorize construction of a Modern Pit Facility capable of manufacturing plutonium pits for nuclear weapons, at an estimated cost of $2 to $4 billion.

Conclusions

There are several technical issues to address before proceeding with site selection or committing to an MPF design. These decisions should be deferred until Congress can more thoroughly assess the MPF and various alternatives while supporting an enhanced research program on plutonium aging. In particular, in 2006, a milestone will be reached in an experiment to estimate the minimum pit lifetime, the result of which will help inform production needs. Further, pit production assessments must be informed by clearer evaluations of future nuclear force structure.

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The APS

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Executive Summary

Plutonium "pits" are the cores of modern nuclear weapons. In order to ensure that the U.S. nuclear arsenal is safe and reliable, plutonium pits are closely monitored for any deterioration due to aging.

The average age of plutonium pits in the U.S. arsenal is 20 years with the oldest being about 26 years old. The *minimum* pit lifetime is currently estimated to be 45 to 60 years, based largely on the modest changes observed in key properties of plutonium samples that are 40 years old.

The pits in the current nuclear weapons stockpile were manufactured at a facility that was shut down in 1989. The National Nuclear Security Administration (NNSA) recently reestablished a limited capability to produce pits at the Los Alamos National Laboratory. The NNSA has proposed an additional Modern Pit Facility (MPF) that could produce, depending on the final design, either 125, 250 or 450 pits per year in single-shift operation, beginning in 2020.

Recent Congressional hearings and associated testimony have indicated that a MPF could be a major budget item for the NNSA. The APS Panel examined the technical issues associated with the MPF because such a large investment in permanent infrastructure is a demanding commitment of resources in the stewardship program.

The APS Panel concluded that there is insufficient technical reason to commit to a site or design for a MPF at this time. Deferring such decisions until at least 2006, the date that the NNSA initially proposed in evaluating the facility's environmental impact, would allow Congress to more thoroughly consider key issues that could significantly affect overall decisions regarding an MPF:

- Pit facility design and site selection should not proceed until there are more precise estimates of future nuclear force structure.

- Site and design decisions should be deferred while the NNSA enhances the research program on plutonium aging. In particular, an experiment is underway which by 2006 will help determine whether pits can be expected to have a minimum lifetime of 60 years. With a 60-year minimum lifetime, the earliest that a pit might need to be replaced is 2038, and there may be no need to commit to a MPF for 15 more years.

- The various production options should be more thoroughly assessed. In particular, the cost and benefits should be evaluated for a small-scale production facility – capable of producing 50 to 80 pits a year in single-shift operation - that has the capability of a modular enhancement to larger production if necessary.

While a pit manufacturing capability is required to maintain the nuclear arsenal, delaying MPF site and design decisions by a few years would provide the time to address key technical issues and ensure that future pit production will be based on good science, good policy, and prudent management of tight federal budgets.

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Contents

I. Background

All nuclear weapons in the U.S. arsenal use chemical explosives to compress a hollow shell of plutonium in order to trigger the nuclear explosion. This shell of plutonium at the core of a nuclear warhead is called the "pit."

The integrity of the pit is critical to the performance of the nuclear weapon. To ensure that the nuclear arsenal is safe and reliable, the National Nuclear Security Administration (NNSA) established an Enhanced Surveillance Campaign (ESC). The ESC closely monitors the pits for any deterioration due to aging.

Two leading causes of potential aging effects are (1) the radioactive decay of the various plutonium isotopes and (2) corrosion. The maintenance of well-sealed pits and the exclusion of foreign contaminants during pit production have virtually eliminated the corrosion problem.[1] Consequently, the ESC's primary activity is to look for potential aging effects due to radioactive decay.

According to nongovernmental estimates, there are currently about 8,000 warheads in the deployed or active stockpile and 3,000 warheads in the inactive stockpile.[2] The average age of the plutonium pits in these weapons is 20 years with the oldest being about 26 years old. The *minimum* pit lifetime is currently estimated at 45 to 60 years.

All the pits in the current U.S. nuclear weapons stockpile were manufactured at the Rocky Flats Plant in Colorado. That facility was shut down in 1989 because of environmental violations.[3] Since that time, Los Alamos National Laboratory has been developing an improved pit production process and in April 2003 succeeded in producing a "stockpile certifiable" pit in its TA-55 plutonium facility.[4] The current NNSA plan is for the TA-55 facility to produce pits for the stockpile at a rate of 10 to 20 pits per year by 2007.[5]

NNSA has determined that the United States requires a pit manufacturing capacity greater than the 20 pits per year that TA-55 is currently scheduled to be able to produce. Specifically, NNSA has proposed building a Modern Pit Facility (MPF) with a single-shift production capacity of 125, 250, or 450 pits per year, beginning operation in about 2020.[6] The NNSA has also specified that the facility be designed to be "agile" with an "ability to simultaneously produce multiple pit types" and "the flexibility to produce pits of a new design in a timely manner."[7]

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[1] "Plutonium: Aging Mechanisms and Weapon Pit Lifetime Assessment" by Joseph C. Martz and Adam J. Schwartz *JOM*, September 2003, http://www.tms.org/pubs/journals/JOM/0309/Martz-0309.html, p5.
[2] Inactive warheads are warheads with their tritium canisters and other "limite-life" components removed. Tritium has a half-life of about 12 years and therefore has to be replenished at invervals of several years.
[3] *Modern Pit Facility Draft Environmental Impact Statement* (hereafter MPF DEIS, National Nuclear Security Administration, June 4, 2003), http://www.mpfeis.com, Summary, S-1.
[4] Los Alamos National Lab, April 22, 2003, http://www.lanl.gov/worldview/news/releases/archive/03-054.shtml
[5] *Nuclear Warhead "Pit" Production: Background and Issues for Congress* by Jonathan Medalia, Congressional Research Service, updated, March 29, 2004, p. 6. Medalia reports that, as of March 2004, a total of 5 certifiable W88 pits had been produced
[6] MPF DEIS, Chapter 2, "Purpose and Need," p. 2-6.
[7] MPF DEIS, Summary, p. S-11.

Production at the TA-55 facility has the potential to be expanded beyond the scheduled 20 pits per year and could in principle be increased to between 80 and 150 pits per year in a single-shift operation. NNSA has given a number of reasons for not pursuing this option. The most important are that a single-shift production capacity of 80 pits per year "does not meet the minimum capacity requirement of 125 pits per year" and that the option to expand TA-55 capacity to 150 pits per year "approaches the cost and schedule of a small newly-constructed modern pit facility, but does not provide the agility or contingent [higher] capacity needed for the long term."[8] Finally, there is concern that maintaining a large production capability at TA-55 would conflict with the necessary science missions of Los Alamos Laboratory.

The House Appropriations Committee challenged the justification for a Modern Pit Facility in July 2003:

> "The fiscal year 2004 budget request is the second budget request delivered to the Committee that is loosely justified on the requirements of the Nuclear Posture Review (NPR) policy document but lacking a formal plan that specifies the changes to the stockpile reflecting the President's decision. The Committee was hopeful that the outcome of the Administration's review would provide a definitive inventory objective for each weapons system to allow the NNSA to plan and execute a program to support defense requirements based on what is needed rather than the continuation of a nuclear stockpile and weapons complex built to fight the now defunct Soviet Union…
>
> "The Committee supports the budget request in fiscal year 2004 for continued conceptual design work on a Modern Pit Facility, but urges the NNSA to look diligently at ways to more effectively utilize TA-55 at Los Alamos National Laboratory to address Stockpile Stewardship Program pit manufacturing requirements in the near term and take a less aggressive planning approach for a new multi-billion dollar facility. The Committee feels the Department's rush to commit to an MPF design and siting decision is premature without the development of a detailed analysis of outyear pit production capacity requirements tied to the 2012 stockpile."[9]

The NNSA's proposal to commit to a Modern Pit Facility has also been questioned by arms control organizations. In particular, these organizations are concerned about the upper end of the proposed size range for the MPF. An MPF with a capacity of 450 pits per year would be able to maintain a stockpile of over 10,000 warheads. Critics argue that this would be inconsistent with U.S. commitments to nuclear disarmament under Article VI of the Nonproliferation

[8] MPF DEIS, Chapter 3, "Alternatives," p. 3-17.

[9] House Appropriations Committee, "Report on the Energy and Water Development Appropriations Bill, 2004 (H.R. 2754)," Report # 108-212, July 16, 2003, http://thomas.loc.gov/cgi-bin/cpquery/T?&report=hr212&dbname=cp108&, pp. 141 ff.

Treaty. Further, they are concerned that NNSA's expressed interest in new pit designs would quite possibly lead to resumed nuclear testing.

The cost estimates of between $2 – $4 billion for the proposed MPF are also of concern, given current Federal budget constraints. Specifically, there is a concern that a multi-billion dollar MPF could potentially jeopardize adequate funding for some elements of the Stockpile Stewardship Program.

In response to these various concerns, the NNSA recently postponed issuing a final Environmental Impact Statement and site-selection decision on the MPF, that was originally scheduled for 2006,[10] while it reconsiders the "scope and timing" of the decision.[11] At the same time, however, it proposes to almost triple its budget for the MPF to $29.8 million in fiscal year 2005 with a planned steady ramp up to $105.2 million in fiscal year 2009.[12]

Regardless of the arms control and economic issues, the plutonium in nuclear weapons cannot be expected to last forever and maintaining the nation's nuclear arsenal will eventually require a pit production capability.

The APS Panel examined the technical issues associated with the MPF because such a large investment in permanent infrastructure is a demanding commitment of resources in the stewardship program. The APS Panel considered the three technical questions that need to be addressed in evaluating the size and urgency of such a pit production capability:

How large a stockpile will the United States have in the future?

How soon and how fast will the existing pits have to be replaced?

Are there alternatives to an MPF that deserve more consideration?

The following sections consider each of these questions in order.

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[10] MPF DEIS, p. S-14.
[11] "NNSA Delays Modern Pit Facility Environmental Impact Statement and Selection of a Preferred Location" (National Nuclear Security Administration press release, Jan. 28, 2004, http://www.nnsa.doe.gov/
[12] *Nuclear Warhead "Pit" Production: Background and Issues for Congress*, Table 1.

II. The Size of the Nuclear Stockpile

The size of the U.S. nuclear stockpile is classified. According to nongovernmental estimates, there were approximately 10,000 warheads in the U.S. stockpile at the beginning of 2004. In addition, according to the same sources, 5,000 of the 12,000 pits stored at NNSA's Pantex warhead assembly/disassembly plant near Amarillo, Texas have been designated as a strategic reserve.[13]

The Strategic Offensive Reduction Treaty (SORT) requires that the number of U.S. "operationally deployed" strategic warheads be reduced to the range of 1,700 to 2,200 by 2012. Most likely, the active stockpile will also decline – perhaps to roughly 5,000 warheads. If no further pits are declared excess, however, the U.S. will still have 15,000 pits in 2012, including 10,000 divided between the inactive stockpile of warheads and the stockpile of reserve pits.

The size of the future stockpile is a critical factor in determining the required pit production capacity. Unfortunately, as indicated in the quote from the House Appropriations Committee report above, the Bush Administration has still not fixed a planning figure for the future size of the U.S. nuclear-weapon stockpile. According to the NNSA:

> "The size and composition of the enduring stockpile are…uncertain. In classified analyses, the NNSA has considered possible futures in which the stockpile size could be reduced to 1,000 total weapons or in which it could be as large as required to meet [the 2001] Nuclear Posture Review requirements."[14]

If pits were produced and retired at a constant rate, then the relationship between stockpile size, production capacity, and pit lifetime would be given by

$$S = C\tau$$

where S is the stockpile size, C is the pit production capacity, and τ is the average pit lifetime. The currently estimated minimum pit lifetime is 45 to 60 years.[15] Thus, a production capacity of 80 pits per year would support a stockpile of between 3,600 to 4,800 warheads, and a capacity of 450 pits per year could theoretically support a stockpile of more than 20,000 warheads.

Pits have not been produced at a constant rate, however. As indicated in Table 1, the pits in nearly all of the warheads in the current stockpile were produced over a period of only 12 years, from 1978 to 1989.[16] If each pit was replaced when it reached a particular age, then the rebuilding period would be approximately 12 years and, even at a rate of 450 pits per year, only 5,400 pits could be replaced.

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[13] "NRDC Nuclear Notebook: Dismantling U.S. nuclear warheads," *Bulletin of the Atomic Scientists*, Vol. 60, No.1 (January/February 2004), pp. 72–74, http://www.thebulletin.org/issues/nukenotes/jf04nukenote.html.
[14] MPF DEIS, Summary, p. S-13.
[15] MPF DEIS, Summary, p. S-12.
[16] The only exception is the W62 warhead for the Minuteman ICBM, which was produced from 1970 to 1976, but is to be retired by the end of Fiscal Year 2009.

Table 1	Approximate production period and total inventory (active + inactive) of warheads in the current stockpile.

Warhead Type	**System**	**Laboratory**[a]	**Production Period**[b]	**Number in Stockpile**[c]
B61-3/4	Tactical bomb	LANL	1979-89	1,100
B61-7	Strategic bomb	LANL	1985-90[d]	470
B61-10	Tactical bomb	LANL	1983-86; 1990-91[e]	200
B61-11	Strategic bomb	LANL	1997[f]	50
W62	Minuteman	LLNL	1970-76	610
W76	Trident	LANL	1978-87	3,200
W78	Minuteman	LANL	1979-82	920
W80-0	SLCM	LANL	1983-90	320
W80-1	ALCM/ACM	LANL	1981-90	1,800
B83-0/1	Strategic bomb	LLNL	1983-91	620
W84	GLCM	LLNL	1983-88	400
W87	MX/Minuteman	LLNL	1986-88	550
W88	Trident	LANL	1988-89	400
Total				10,640

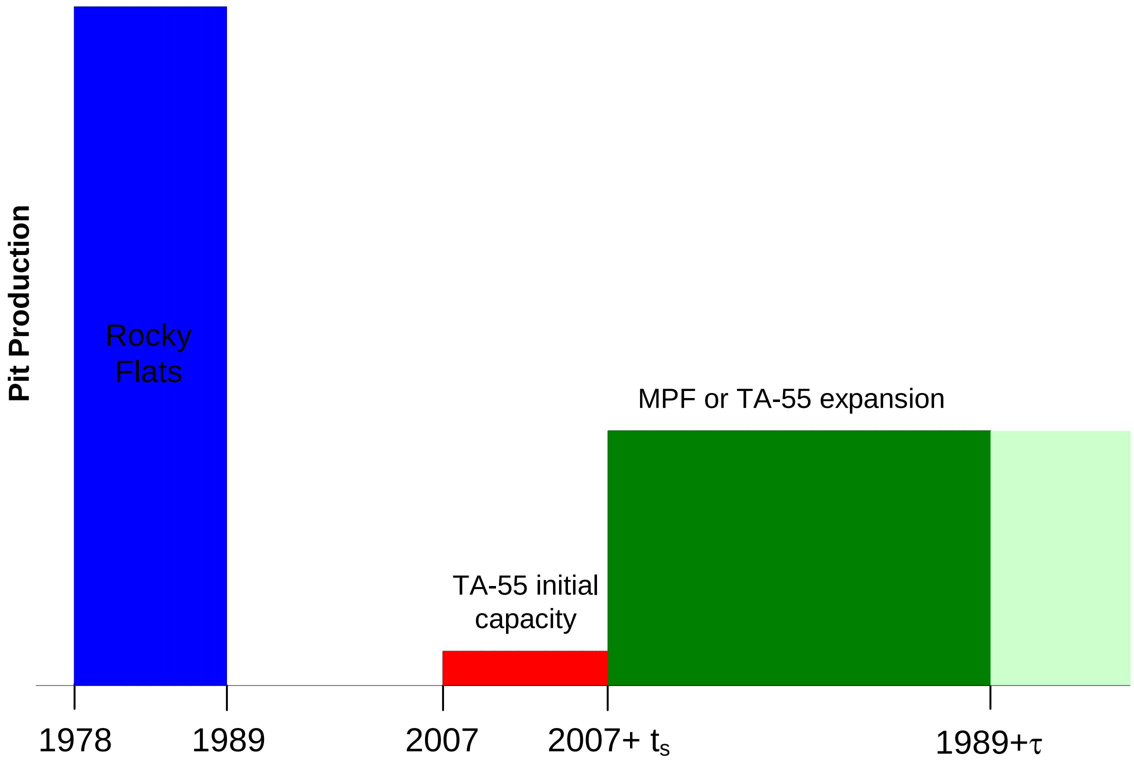
[a]LANL = Los Alamos National Laboratory; LLNL = Lawrence Livermore National Laboratory
[b]Dates of warhead assembly. It is unlikely that the pits were produced much earlier than the first warhead.
[c]Natural Resources Defense Council, http://www.nrdc.org/media/docs/020213a1.pdf.
[d]The B61-7, produced from 1985-90, is a modified B61-1 and may contain a somewhat older pit.
[e]The B61-10 was produced using the physics package from the W85, which was produced from 1983-86.
[f]The B61-11, produced in 1997, is a modified version of the B61-7.

It is not necessary to replace every pit when it reaches a particular age, however. For example, if pits produced in 1978 were replaced when they were 40 years old and those produced in 1989 were replaced when they were 60 years old, the rebuilding period would be increased from 12 to 32 years. At a rate of 80 to 450 pits per year, 2,500 to 14,000 pits could be replaced over this 32-year period.

Figure 1 illustrates the relationship between stockpile size, production capacity, and pit lifetime, assuming an interim production capacity is established at TA-55 in 2007 and that TA-55 is expanded or an MPF begins operation some years later. The maximum stockpile size, S, when the youngest pits (which were built in 1989) reach the maximum pit lifetime, τ, is given by

$$S = C_{int}\, t_s + C(\tau - t_s - 17)$$

where C_{int} is the interim capacity of TA-55 (assumed here to be 20 pits per year) and t_s is the number of years that elapse between establishing the interim capacity and the start of production at an MPF or an expanded TA-55 with capacity C. Thus, assuming an expanded TA-55 with a capacity of 80 pits per year begins operation in 2015 and a pit lifetime of 60 years, a total stockpile of about 3,000 pits could be replaced by 2050 - sufficient to maintain a SORT-sized arsenal of deployed strategic warheads plus several hundred spares.



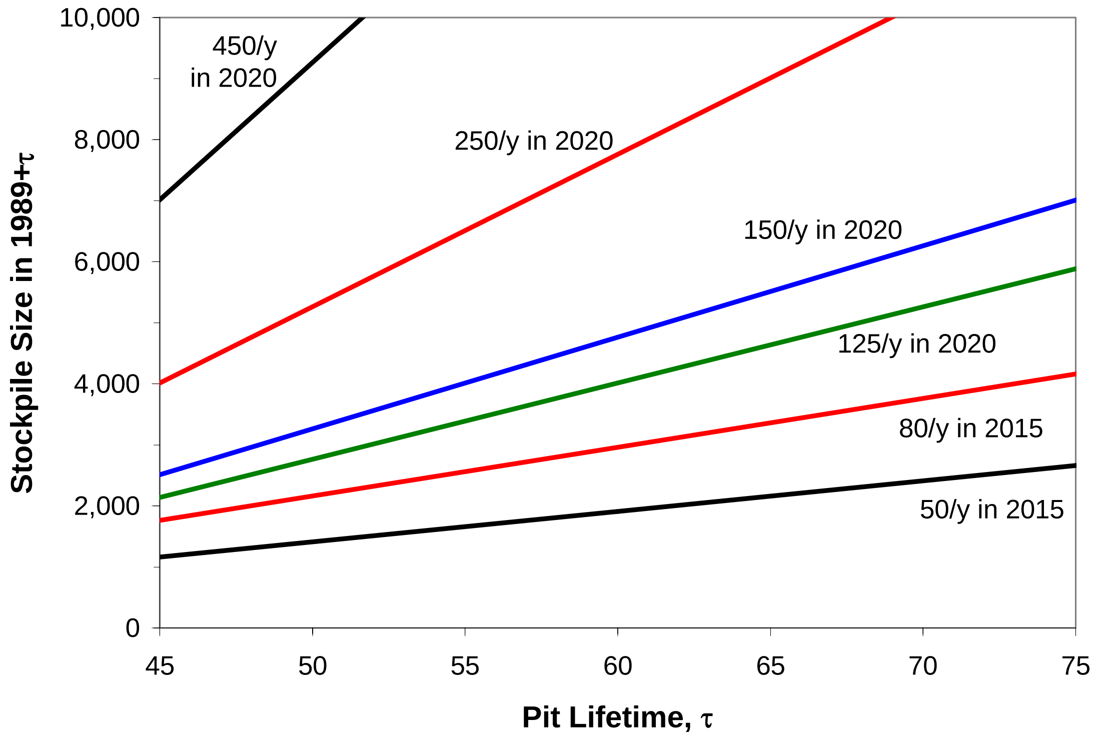


Figure 1	Stockpile sizes for various pit production capacities, assuming an interim production capacity of 20 pits per year at TA-55 beginning in 2007.

The NNSA lists a number of additional considerations that bear on the sizing of the MPF:

> "The capacity of a MPF needs to support both scheduled stockpile pit replacement at end of life and any 'unexpected' short-term production…to address, for example, a design, production, or unexpected aging flaw identified in surveillance, or for stockpile augmentation (such as the production of new weapons, if required by national security needs)." [17]

Surge capacity to deal with unexpected problems could be provided without building a larger facility, simply by training more workers and using multiple shifts. Capacity could be doubled or tripled relatively quickly in an emergency.

The need for additional production capacity to deal with unexpected problems is, however, substantially reduced by the fact that the United States plans to maintain a diversity of warhead types and a considerable stockpile of spare and inactive warheads.

Under SORT, the U.S. will have at most 2,200 warheads "operationally deployed" in 2012 (i.e., mounted on ballistic missiles or stored at air bases where strategic bombers are deployed).[18] These will be of seven warhead types: four for ballistic warheads, one air-launched cruise missile warhead, and two bombs. The W62 warhead is to be retired, leaving U.S. intercontinental ballistic missiles with two warhead types: the W78 and the W87. Similarly, U.S. submarine-launched ballistic missiles will have two warhead types: the W76 and the W88. Finally, strategic bombers will have the W80-1 for air-launched cruise missiles (backed up by the W-84 GLCM warhead in the inactive stockpile) and two types of bombs, the B61 and B83. Thus, if a warhead type develops a problem, there will in all cases be a substitute in the stockpile.

The possibility of a "common mode failure" is sometimes raised, in which a particular aging problem affects many warhead types and requires the replacement of all or a large fraction of the pits in the stockpile. This theoretical vulnerability of the current stockpile is aggravated by the relatively short period over which the pits were produced. The most effective way to ameliorate it will be to produce replacement pits at a lower rate over a longer period of time.

The only specific new warhead being examined is the "robust nuclear earth penetrator, for the study of which, the NNSA has requested $27.6 million for fiscal year 2005."[19] Since the current idea is to use an existing pit inside a penetrating shell, this would not require new pit production.

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[17] MPF DEIS, Summary, p. S-15.

[18] Although the U.S. might also stockpile several hundred non-strategic warheads, and many thousands of reserve warheads and pits, there would be little or no need to replace these on an emergency basis should reliability problems be discovered.

[19] Statement of Spencer Abraham, Secretary, U.S. Department of Energy Senate Committee on Armed Services, March 23, 2004

However, a large-scale production facility could be used to manufacture new pits for new types of warheads. If the additional capacity is intended to provide this option of new warhead production, then DOD should justify the need for new warheads before NNSA builds the additional capacity to produce them.

Conclusions:

- Decisions regarding MPF design should not be made until there is a more precise estimate of the size of the future nuclear arsenal.
- If the minimum pit lifetime is found to be 60 years, then a production rate of 80 pits per year could support an arsenal of 1,700 to 2,200 deployed strategic warheads plus several hundred spares and non-strategic warheads. That is the reduced arsenal size to which the U.S. is pledged by the recently concluded Strategic Offensive Reductions Treaty (SORT) with Russia.
- In determining the size of a future production capability, the NNSA should not create unnecessary, excess capacity, particularly since multi-shift operation inherently provides back-up capacity. Yet, much of the capacity provided by an MPF with a production capability of 450 pits per year, would be unnecessary for maintaining a SORT-sized arsenal. If the additional capacity is intended as a “surge” capability that allows for more rapid warhead replacement, then, given warhead interchangeability, NNSA should clarify under what scenarios a surge capability would be necessary. If the additional capacity is intended to provide the option of new warhead production, then DOD should justify the need for new warheads before NNSA builds the additional capacity to produce them.

III. Pit Lifetime

NNSA currently estimates that the minimum pit lifetime is at least 45 to 60 years. This estimate is based on the fact that "measurements to date have not shown any significant degradation of pits over approximately 40 years." [20] Of course, many additional measurements are called for to make this a robust conclusion.

The NNSA has samples of weapon-grade plutonium that are 40 years old. These samples show insignificant degradation and virtually no corrosion. According to the NNSA-commissioned review of the subject:

> "Experience from stockpile surveillance programs reflects this point: pits have remained remarkably pristine and free of corrosion, especially since the adoption of modern cleaning and sealing methods... [21]
>
> "On the basis of careful evaluation of the [aging] effects described above through extensive characterization of old pits, modeling, and preliminary design sensitivity calculations…an initial assessment of minimum pit lifetimes has been derived. Evaluation of the oldest samples of plutonium metal, both metal of oldest absolute age (40 years) as well as the oldest samples most directly comparable to the enduring stockpile (25 years) have shown predictably stable behavior. The many properties that have been measured to date, such as density and mechanical properties have shown only small changes and detailed microstructural studies have been correlated to these changes in properties. The response of each system to potential changes is specific to each particular design. Based on this assessment, current estimates of the minimum age for replacement of pits is between 45 and 60 years."[22]

To improve these estimates, a number of theoretical calculations and experiments, including an "accelerated-aging" experiment, are currently underway that will be used as a basis for joint laboratory report due in 2006 that is to establish whether some or all pit types can be expected to have a minimum lifetime of 60 years. NNSA experts describe the "accelerated-aging" experiment as follows:

> "The process of alpha decay within plutonium can be accelerated by the addition of isotopes with shorter half-lives. An alloy of normal weapon-grade plutonium mixed with 7.5% of the Pu-238 isotope will accumulate radiation damage at a rate 16 times faster than weapon-grade material alone. This is a useful tool to evaluate

[20] "Plutonium aging: Implications for pit lifetimes" by J. Martz (LANL) and A. Schwartz (LLNL), LA-UR-03-0259 in MPF DEIS, Appendix G, p. G-65. An article expanding on this report, "Plutonium: Aging mechanisms and weapon pit lifetime assessment" by Joseph Martz and Adam Schwartz, has been published in *JOM: The member journal of the Minerals, Metals & Materials Society,* September 2003, http://www.tms.org/pubs/journals/JOM/0309/Martz-0309.html.

[21] "Plutonium aging: Implications for pit lifetimes," MPF DEIS, Appendix G, pp. G-63.

[22] "Plutonium aging: Implications for pit lifetimes," p. G-64.

> extended-aged plutonium (up to 60-years equivalent and possibly beyond) within a few years. Critically, acceleration of the input or radiation damage must be matched by acceleration of the subsequent annealing and diffusion of that damage. We accomplish this subsequent acceleration by raising the temperature at which the samples are stored. These processes are thermal in nature, and the activation energy (a term which describes the energy required to activate a process) is different for each specific mechanism. Unfortunately, there is no single temperature at which the thermal diffusion of this damage will be equivalently and perfectly matched to the initial acceleration of the damage input. As a result, the accelerated aging experiments are carried out at three different temperatures…
>
> By early 2006, these samples will have reached an equivalent age of 60 years, and measurements of their properties (and comparison to aging models) [will] form a key milestone in our estimate of pit lifetimes."[23]

It is critical that NNSA provide adequate funding so that this full program of experiments and analysis can be carried through.

Conclusions:

- Decisions regarding MPF design or site should not be made before an experiment is completed in 2006 that will help determine whether pits can be expected to have a *minimum* lifetime of 60 years. With a 60-year minimum lifetime, the earliest that a pit might need to be replaced is 2038. In that case, there would be no need to commit to a large-scale production capability for at least 15 more years.
- If, in 2006, pits are estimated to have only a 45-year lifetime, then site selection and design commitment for MPF could begin. The oldest pits would reach their 45-year lifetime in 2023, still leaving 17 years to build an MPF. In the meantime, hundreds of replacement pits could be produced at the current TA-55 facility.
- Deferring site selection and design affords NNSA the time to develop a more vigorous program in plutonium aging, one that spans a greater range of materials and uses.

[23] "Plutonium aging: Implications for pit lifetimes," pp. G-62, G-65.

IV. Production Options

Deferring site selection and design decisions offers the opportunity to explore more creative solutions to the complex problem of pit production than the current proposals for an MPF. Specifically, it will provide the opportunity to better address issues of cost, science, and need.

Proposed alternatives to a large-scale MPF include: proceeding exclusively with TA-55 production; adding a wing to the existing TA-55 to provide additional production space; or, building a small-scale production facility at a new site that has the capability for modular expansion to large production. These options are considered briefly below.

A study done by Los Alamos for the U.S. National Nuclear Security Administration (NNSA) found that, for an expenditure of $0.5-0.7 billion, it would be possible by 2014-16 to have a production line in TA-55 that could produce all pit types in the U.S. "enduring stockpile" (except for that in the B83 bomb) at a rate of 50 to 80 pits per year, operating 40 hours a week. [24]

With a production rate of 80 pits per year starting in 2015, TA-55 could produce 2,800 replacement pits by 2049, when the youngest pits in the current stockpile would be 60 years old. An additional 100 to 200 replacement pits could be produced at TA-55 between now and 2015. Thus, the TA-55 facility could reasonably be expected to be able to maintain a stockpile of up to 3,000 warheads, assuming a capacity of 80 pits per year and a minimum pit lifetime of 60 years. If TA-55 fails to meet the 80 pit per year schedule in single shift operation, double-shift operation is still an option.

The study also explored the possibility of expanding the TA-55 facility. It found that, for a total expenditure of $1.2-1.6 billion, an additional wing could be added to TA-55 and its production capacity increased so that it could produce by 2020 all the pit types in the enduring stockpile at a rate of 150 pits per year, including the capability of simultaneously producing two different types of pits.

The original design of TA-55 was based on modularity – the capability of adding additional production lines to accommodate the option for increased capacity in the future. Indeed, the United Kingdom copied the TA-55 design and exploited this inherent modularity.

Production options that adopt modularity offer two clear advantages over a large-scale MPF. Modularity provides hedging options should stockpile requirements or unforeseen problems necessitate expanding capacity. And, modular production lines provide the greatest flexibility at a time of significant budget pressure.

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[24] "Summary of TA-55/PF-4 upgrade evaluation for long-term pit manufacturing capacity" by S.T. Boertigter, D.E. Kornreich, and W. Barkmen (Los Alamos National Laboratory, LA-UR-03-2711 in MPF DEIS, Appendix G, p. G-54. More detail on the current use of space in TA-55 facility and an earlier analysis for the expansion of its single-shift production capacity to 50 pits per year (80 pits per year with multiple shifts) may be found in the *Site-Wide Environmental Impact Statement for Continued Operation of the Los Alamos National Laboratory, Vol. II, Part II,* "Enhancement of plutonium pit manufacturing" (U.S. Department of Energy, DOE/EIS-0238, 1999).

Another option that should be more thoroughly explored is the development of a small-scale modular production facility at a new site. This has been previously proposed as a scalable facility, with modules capable of 50-pit-year production being added on to the facility as necessary.[25] While there is a clear benefit to the design flexibility afforded by a new modular facility, it must be carefully weighed against existing TA-55 options. In particular, the TA-55 options should be assessed for the cases of plutonium lifetimes ranging up to 60 years and a SORT-sized arsenal.

There are several issues that must be addressed in assessing the TA-55 options. First, the TA-55 facility plays a critical role in the science and engineering associated with plutonium assemblies for weapons and it is also an important tool for maintaining stockpile reliability. While it offers the opportunity for enhanced pit production, care must be taken to preserve its essential role in plutonium stewardship and stockpile surveillance.

Further, the previous study of a TA-55 upgrade cautioned that the highest-capacity option was subject to "high execution risk…due to the possibility of an unforeseen event during the construction of new floor space that could disrupt both the upgrade and on-going TA-55 manufacturing and certification activities."[26] Finally, the fact that the production date for TA-55 to produce its first certifiable pit slipped from 1998 to 2003 created a credibility problem for its management which have not been completely eliminated by the ramp up in its production over the past year.[27]

All these production options should be reviewed by independent organizations.[28] The assessments should determine the causes of past delays at TA-55 and whether the production needs could be better addressed at another site.

Deferring irreversible decisions—such as site selection and MPF design—until after 2006 affords the time to more thoroughly examine the various production options proposed above. It also provides the time to include in the assessments the results of the pit-longevity experiment (described in the previous section) that will be completed in 2006. Finally, it will allow for more accurate estimates of future nuclear force structure to be included in sizing considerations.

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[25] John Foster, et. al.,"Panel to Assess the Reliability, Safety, and Security of the United States Nuclear Stockpile", April 11, 2003.
[26] Ibid.
[27] *Nuclear Warhead "Pit" Production: Background and Issues for Congress,* pp. 6-8.
[28] Such organizations include the National Academy of Science and JASON, a group of academic experts that do studies of this type for the Departments of Defense and Energy.

Conclusions:

- The numerous options for pit production must be more thoroughly explored before selecting an MPF site or design.
- A production capacity of 80 pits/year may be more than adequate to accommodate all foreseeable production needs. The capability of meeting this production need at TA-55 should be more thoroughly examined particularly regarding costs, timeline, impact on the Los Alamos science mission, and technical capabilities. At the same time, modular production at a new site should be more thoroughly explored.
- To strengthen the basis for a decision regarding a pit production facility, Congress should consider seeking such analysis through independent organization such as NAS or JASON. There is adequate time for these groups to report their findings. Suspending site and design decisions until 2006 will not jeopardize the reliability of the existing stockpile.

Appendix I: Purpose, Authors and Reviewers

While a pit manufacturing capability is required to maintain the nuclear arsenal, recent Congressional hearings and associated testimony have highlighted plans for a Modern Pit Facility that would eventually represent a major budget item for the National Nuclear Security Administration and the overall stewardship program.

The American Physical Society Panel on Public Affairs examined the technical issues associated with the MPF because such a large investment in permanent infrastructure is a demanding commitment of resources in the stewardship program. The authors concluded that delaying the decision for the MPF by a few years would provide the time to address key technical issues and ensure that a decision on future pit production will be based on good science, good policy, and prudent management of tight federal budgets.

This Discussion Paper was drafted by the National Security Subcommittee of the APS Panel on Public Affairs (POPA). It was then reviewed, edited, and unanimously supported by the entire POPA committee. POPA members include:

John Ahearne
Arthur Bienenstock, Chair
John Bahcall
Steven Block
Peter Bond
Brian Clark
Morrel Cohen
Daniel Cox
Peter Eisenberger
Martin Einhorn
Steve Fetter
Yogendra Gupta
Roger Hagengruber
Steven Koonin
Barbara Levi
Joel Primack
Ernest J. Moniz
Wayne Shotts
Frank von Hippel
Jennifer Zinck
Francis Slakey, Subcommittee Advisor

This Discussion Paper was also reviewed by numerous national laboratory scientists and leading independent researchers with expertise in the field of plutonium aging. All the reviewers' comments were addressed in the development of the final paper; however, the conclusions are the responsibility of the authors alone.

(dollars in thousands)

FY 2010 Actual Approp	FY 2011 Request	FY 2012 Request

Laboratory/Utility/Office Building (RLUOB) is complete, and installation of associated equipment is underway and ahead of schedule. Following a series of cost reviews, the updated cost range estimate based on 45 percent design maturity for the CMRR Total Project Cost (TPC) is $3,700,000,000 to $5,800,000,000. This updated cost range estimate reflects bounding cost estimate data from the contractor and government contingency. Consistent with NNSA's increased emphasis on project management rigor, baseline cost and schedule will not be finalized until the project achieves 90 percent design maturity. The project is scheduled to achieve 90 percent design maturity in FY 2012, and the Department will set the performance baseline in FY 2013. The increased funding level in the FY 2012-FY 2016 period is needed to support the required schedule of construction completion in FY 2020 and a ramp-up to full operations by FY 2023. For FY 2012, the amounts shown in the line item request for CMRR represent TPC, which includes both Construction and OPC. Construction and OPC funds will be executed through the line item. Funds will be obligated and recorded in the appropriate object classes (object class 32.0 and 25.4) as defined in Office of Management and Budget Circular A-11.

The UPF at the Y-12 Complex will replace deteriorating 50-year-old facilities that do not meet current standards, are increasingly expensive to maintain, and are technologically obsolete. When complete, the UPF will allow a substantial reduction in the footprint of the secure area of the site and associated maintenance and security costs. The UPF will support the nation's nuclear weapons stockpile, down blending of enriched uranium in support of nonproliferation, and provide uranium as feedstock for fuel for naval reactors. Following a series of cost reviews, the updated cost range estimate based on 45 percent design maturity for the UPF TPC is $4,200,000,000 to $6,500,000,000. This updated cost range estimate reflects bounding cost estimate data from the contractor, government contingency, and an independent cost estimate by the Department's Office of Cost Analysis. Consistent with NNSA's increased emphasis on project management rigor, baseline cost and schedule will not be finalized until the project achieves 90 percent design maturity. The project is scheduled to achieve 90 percent design maturity in FY 2012, and the Department will set the performance baseline in FY 2013. The increased funding level in the FY 2012- FY 2016 period is needed to support the NNSA's priority to phase out operations in Building 9212 and move required chemical processing activities from Building 9212 into UPF in FY 2020, with a ramp-up to full operations in UPF by FY 2024. For FY 2012, the amounts shown in the line item request for UPF represent TPC, which includes both Construction and OPC. Construction and OPC funds will be executed through the line item. Funds will be obligated and recorded in the appropriate object classes (object class 32.0 and 25.4) as defined in Office of Management and Budget Circular A-11.

The Transuranic (TRU) Waste Facility Project at LANL will allow the site to comply with an Order of Consent with the State of New Mexico which requires the cleanup and vacating of Technical Area 54. The TRU Waste Facility will receive, process, and ship newly generated wastes to the Waste Isolation Pilot Plant (WIPP). The facility will support all nuclear operations at LANL that generate TRU waste.

04-D-125, Chemistry and Metallurgy Research Building Replacement (CMRR) Project, Los Alamos National Laboratory (LANL), Los Alamos, New Mexico Project Data Sheet (PDS) is for Construction

1. Significant Changes

The CMRR project will construct two principal structures in three project phases. The first phase provides funding to construct the Radiological Laboratory/Utility/Office Building (RLUOB). The second phase, the RLUOB Equipment Installation (REI) effort, procures and installs the Special Facility Equipment (SFE) for the RLUOB. The third phase constructs the Nuclear Facility (NF). This data sheet presents the budget, costs, baselines and activities for each of the three phases separately.

RLUOB: The most recent DOE O 413.3B approved Critical Decision (CD) is a tailored CD-4, Approve Project Closeout, approved on June 24, 2010. The RLUOB was baselined in 2005 with a TPC of $164,000. Construction of the building structure and related systems has been successfully completed; the facility will begin operations at the conclusion of the next phase of the CMRR project (REI).

REI: The most recent DOE O 413.3B approved CD is CD-2/3, Approve Performance Baseline and Start of Construction, approved on July 17, 2009 with a TPC of $199,400 and a CD-4 date of April 30, 2013. This phase of the project is underway. At REI CD-4, the RLOUB will be functionally complete and turned over to operations. Project performance will be assessed with the completion of both RLUOB and REI for a combined total cost of $363,400.

NF: The most recent DOE O 413.3B approved CD is CD-1, Approve Alternative Selection and Cost Range that was approved on May 18, 2005 with a preliminary cost range of $745,000- $975,000 and CD-4 in FY 2013. In April 2010, the CMRR Los Alamos National Security LLC (LANS) contractor completed an updated cost range estimate that reflected 45 percent engineering design maturity, changes in the assumptions for site seismic data, incorporation of lessons learned from previous nuclear projects in nuclear quality assurance construction, resolution of safety concerns identified by the Defense Nuclear Facilities Safety Board, and incorporation of commercial data on material costs and estimated escalation assumptions. The updated LANS cost range estimate based on 45 percent design is between $3,710,000 and $5,860,000, and is under review by NNSA.

The CMRR project team continues to work with the DOE Office of the Chief Financial Officer (CFO), the US Army Corps of Engineers (USACE) and the Department of Defense (DoD) Cost Assessment and Program Evaluation (CAPE) office to provide independent validation of the updated cost range estimate provided by LANS. In September 2010, the USACE completed a review of the methods and procedures used to develop estimates for CMRR design efforts resulting in improvements for transparency in the provided estimate. These improvements are applicable to the overall project estimation effort. The USACE will continue to work with the project team in future reviews. The DoD CAPE office will conduct an independent cost review in FY 2011.

Following reconciliation of the series of independent cost reviews, NNSA will establish an updated cost range estimate that will reflect approximately 45 percent design maturity. Additional reviews and updates to cost range estimates are anticipated as the design continues to mature. Consistent with

The Hazard from Plutonium Dispersal by Nuclear-warhead Accidents

Steve Fetter and Frank von Hippel

Published in ***Science and Global Security***, Vol. 2, No. 1 (1990), pp. 21–41.

Nuclear weapons are carefully designed to have an extremely low probability of exploding accidentally with an appreciable yield—even if they are involved in a high-speed crash, struck by a bullet or consumed in a fire.[1] The principal concern when nuclear warheads are involved in such accidents is the possible dispersal of plutonium into the environment. In particular, an explosion could disperse a significant fraction of the plutonium in a warhead as particles of respirable size.[2]

There are two incidents of which we are aware in which the chemical high explosive (HE) in U.S. nuclear warheads exploded and contaminated an area with plutonium:[3]

- In January 1966, over Palomares, Spain, a mid-air collision between a B-52 and its refueling aircraft resulted in four bombs from the B-52 being released. The braking parachutes of two bombs failed completely and they struck the ground at high speed. The HE exploded, and plutonium was widely dispersed. Cleanup and reparation cost $100 million.

- In January 1968, near Thule, Greenland, a fire broke out on a B-52. The bomber was abandoned and crashed into the ice at high speed and burned; the HE in the four bombs it carried exploded, spreading plutonium widely over the ice.[4]

Almost immediately after the Thule accident, the U.S. Air Force stopped routinely flying its bombers with nuclear weapons. In addition, most U.S. nuclear

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[1] U.S. Nuclear weapons are designed so that "in the event of a detonation initiated at any one point in the high explosive system [rather than multiple points, which would occur if the authorization code were properly entered and the environmental sensors registered the design launch-to-target sequence], the probability of a nuclear yield greater than 4 pounds [1.8 kilograms] TNT equivalent shall not exceed one in one million." U.S. Arms Control and Disarmament Agency, ***Fiscal Year 1979 Arms Control Impact Statements***, p. 92.

[2] A survey of experiments involving the burning of plutonium metal in hot fires found that the fraction of plutonium converted into a respirable PuO_2 aerosol ranges from less than 0.001 percent to a few percent. Ralph Condit, ***Plutonium Dispersal in Fires: Summary of What is Known*** (Livermore, CA: Lawrence Livermore National Laboratory, 1986), p. 10.

[3] Ibid., p. 11.

[4] For a report on measurements of plutonium contamination and of the cleanup, see USAF Nuclear Safety Study 65 (Kirtland AFB, NM: Directorate of Nuclear Safety, 1970), part 2, "Project Crested Ice."

warheads designed during the last decade use “insensitive high explosive” (IHE), which is unlikely to be detonated by even high-speed impacts.

However, many of the older warheads still in the U.S. nuclear arsenal and, for various reasons, a few of the newer ones—most notably the W88 warhead for the Trident II—still contain ordinary HE. Recently, the U.S. weapon laboratories have chosen to raise the safety problems of these warheads as an issue.[5] The purpose of this article is to offer some perspective on this concern.

Consider a hypothetical worst-case accident in which the HE in several nuclear warheads explodes. Based on experiments and calculations, it has been estimated that 10–100 percent of plutonium contained in the warheads, with a best estimate of 20 percent, could be converted by such explosions into a PuO_2 aerosol of respirable size (median aerodynamic diameter in the range of 5 microns or less).[6] If we assume a missile carrying about 10 warheads, and that each of the warheads contains approximately 3 kilograms of plutonium, then the resulting aerosol would contain on the order of 10 kilograms of PuO_2.[7]

HEALTH RISKS FROM PLUTONIUM AEROSOLS

The principal risk from exposure to a plutonium aerosol is via inhalation: most of the radiation emitted by plutonium is in the form of alpha particles, which have such short range (about 50 microns in tissue) that they cannot even penetrate the skin. External radiation from the passing cloud and from plutonium deposited on the ground can therefore be neglected.[8] For an aerosol of 1-micron median aerodynamic

[5] R. Jeffrey Smith, “Defective Nuclear Shells Raise Safety Concerns,” ***Washington Post***, 23 May 1990, A-1. In a letter to Senator Kennedy, dated 9 July 1990, Brent Scowcroft, President Bush’s national security advisor, argued that “recent revelations regarding the safety of certain warheads underscores the importance of testing.”

[6] ***Supplementary Documentation for an Environmental Impact Statement Regarding the Pantex Plant*** (Los Alamos National Laboratory, report LA-9445-PNT-D, 1982); ***Report on the Safety Criteria for Plutonium-Bearing Nuclear Weapons*** (Washington, DC: U.S. Atomic Energy Agency, report RS/5640/1032, 23 January 1973; declassified with deletions, 9 January 1989), p. 10.

[7] We infer from note 6 that at least some nuclear weapons contain plutonium-238 to power a radioisotope thermoelectric generator (RTG). The amount of plutonium-238 depends on the power requirements for nuclear weapons; 1 gram of plutonium-238 generates about 0.57 watts of heat, which could be converted to no more than 0.06 watts of electric power. Although 14.5 grams of plutonium-238 presents about the same health hazard as 4 kilograms of plutonium-239 (assuming the hazard scales with radioactivity), it could only be used to generate about 1 watt of electrical power. If power requirements are greater than 1 watt, then plutonium-238 should be considered in a hazard analysis. We do not, however, know what the power requirements of nuclear weapons are, and in any case the plutonium-238 in the RTG should be much better protected from dispersal during an accident than the plutonium core. We therefore ignore the contribution of plutonium-238 to health effects in this paper, although we flag the issue here.

[8] The amount of the aerosol inhaled in proportional to its concentration c_0 in the air (measured in mg/m^3) and the length of exposure (T_0). The dose due to inhalation will then be $D_i b T_0 c_0$, where b is the breathing rate (about

diameter, about 15 percent of the inhaled PuO_2 would be retained in the deep lung with a retention half-life of about 1.4 years.[9]

Health effects from radiation exposure are often divided into two categories: illnesses and deaths due to high doses, occurring within a year or so after exposure, and cancers due to low doses, occurring during the remainder of the lives of the exposed population, starting a few years after exposure. As shown in the appendix, high-dose effects are unlikely even in a worst-case plutonium-dispersal accident—especially beyond the boundary of a military base. We therefore focus here on the cancer risk.

The principal hazard from exposure to lower concentrations of PuO_2 aerosols is an increased probability of cancer of the lung and of other organs to which the plutonium is transported, particularly the bone. A recent review of the risks associated with low radiation doses from inhaled alpha emitters obtained a (very rough) risk estimate of one cancer death per 1,400 lung-rad and 900 to 12,000 bone-rad for inhaled PuO_2.[10]

The 30-year dose-conversion factors in the literature for lung and bone-surface doses range respectively from 1,600–3,700 and 3,200–11,000 rads per inhaled milligram of $^{239}PuO_2$ aerosol with a median aerodynamic diameter of 1 micron.[11]

$3.3 \cdot 10^{-4}$ m^3/s for an adult male involved in light activity) and D_i is the dose per milligram of plutonium aerosol inhaled. Below, we will see that $D_i \approx 3{,}800$ and 7,600 rads per milligram for the lung and bone-lining cells—the organs in which the cancer risk would be greatest following the inhalation of PuO_2. The external whole-body dose from the cloud would be $D_c c_0 T_0$ and the external dose from plutonium deposited on the ground would be $D_g c_0 T_0 vT$. $D_c \approx 1.2 \cdot 10^{-8}$ rad $m^3\ mg^{-1}\ s^{-1}$, $D_g = 6.6 \cdot 10^{-10}$ rad $m^2\ mg^{-1}\ s^{-1}$ for plutonium–239, v is the deposition velocity (of order 10^{-2} meters per second in the absence of rain), and T is the duration of exposure to the contaminated ground in seconds. The ratio of cloud to inhalation dose is therefore $D_c/(bD_i) \approx 10^{-8}$, and the ratio of the ground to lung inhalation dose is $(D_g Tv)/(bD_i) \approx 4 \cdot 10^{-12}T$. Since the lung would account for a significant fraction of all cancers caused by external whole-body gamma radiation, the cloud dose brings with it negligible risk, and it would take about 10,000 years for the integrated ground dose to equal the inhalation dose. The ratios for plutonium–239 are similarly low. See Steve Fetter, ***Internal Dose Conversion Factors of 19 Target Organs and 9 Irradiation Times and External Dose-rate Conversion Factors for 21 Target Organs for 259 Radionuclides Produced in Potential Fusion Reactor Materials***, (Idaho Falls: Idaho National Engineering Laboratory, report EGG-FSP-8036, 1988).

[9] ***Reactor Safety Study*** (Washington, DC: U.S. Nuclear Regulatory Commission, report NUREG-75/014, 1975), appendix VI, pp. D-2–D-7.

[10] ***Health Risks of Radon and Other Internally Deposited Alpha-Emitters: BIER IV*** (Washington, DC: National Academy Press, 1988), p. 332-334.

[11] According to table 23 of ***Ionizing Radiation: Sources and Biological Effects*** (New York: United Nations, 1982), the average dose commitment to the human lung and the bone-lining cells from the inhalation of PuO_2 from atmospheric nuclear testing is 1.6 and 4.8 millirads per becquerel, respectively. Since plutonium-239 has a specific activity of 0.06204 curies per gram, this translates to 3,700 and 11,000 rads per milligram.

Reactor Safety Study (Washington, DC: U.S. Nuclear Regulatory Commission, 1975), table VI D-2, gives a 30-year dose to the lung and bone of $2.9 \cdot 10^8$ and $5.2 \cdot 10^8$ rem per curie. Since the study set Q = 10 rem per rad for alpha particles, this translates to 1,800 and 3,200 rads per milligram.

We use the values of 3,200 and 6,500 rads per milligram here.[12] After correcting for the 6 percent plutonium–240 in weapon-grade plutonium (WgPu),[13] the lung and bone dose-conversion factors are 3,800 and 7,600 rads per milligram, respectively. The total (lung plus bone) cancer risk is therefore 3 to 11 cancer deaths per milligram of WgPu aerosol inhaled.

For comparison, the method of estimating cancer risk advocated by the International Commission on Radiological Protection (ICRP) is to use an "effective dose equivalent" (EDE), which is the weighted average of the dose to certain organs, with the weights determined by the relative probability that a fatal cancer will occur in that organ after a uniform whole-body dose. The EDE for $^{239}PuO_2$ aerosol is 15,000 rem per milligram, or 18,000 rem per milligram for WgPu. Dividing by the ICRP risk factor of 2,000 rem per cancer death[14] would give 9 cancer deaths per milligram of WgPu inhaled.

In the appendix on high-dose effects, it is estimated from experimental data on beagle dogs that the risk of death from pulmonary neoplasia (a cancer) would be approximately 100 percent for the inhalation by a human adult of more than 0.08 milligrams of WgPu, if early death did not occur first as a result of some other cause. If this risk were extrapolated linearly to lower exposures, it would correspond to 12 cancer deaths per milligram of WgPu inhaled.

Thus, three different methods of estimating cancer risk from inhalation of PuO_2 give risk factors in the range of 3 to 12 cancer deaths per milligram of WgPu inhaled.

D.E. Dunning, Jr., G.G. Killough, S.R. Bernard, J.C. Pleasant, and P.J. Walsh, "Estimates of Internal Dose Equivalent to 22 Target Organs for Radionuclides Occurring in Routine Releases from Nuclear Fuel-Cycle Facilities," vol. III, ORNL/NUREG/TM-190/V3 (Oak Ridge: Oak Ridge National Laboratory, 1981), pp. 43-44, give 50-year DCFs for lung and bone surfaces of 580 and 4,160 rem per microcurie. After dividing by the assumed Q = 20 rem per rad for alpha particles and multiplying by the ratio of the 30-year and 50-year doses given by Fetter, this translates to 1,600 and 9,300 rads per milligram.

[12] Steve Fetter, "Internal Dose Conversion Factors of 19 Target Organs and 9 Irradiation Times and External Dose-rate Conversion Factors for 21 Target Organs for 259 Radionuclides Produced in Potential Fusion Reactor Materials," (Idaho Falls: Idaho National Engineering Laboratory, 1988), addendum, gives 30-year lung and bone surface doses of $2.9 \cdot 10^8$ and $5.2 \cdot 10^8$ rem/Ci, respectively. Since Q = 20 rem/rad for α-particles in this study, this translates to 3,200 and 6,500 rad/mg of ^{239}Pu.

[13] The specific activity of fresh weapon-grade plutonium is 1.17 times that of pure plutonium–239. After one half-life (14 years) of plutonium–241, the activity would increase by an additional 10 percent because of the alpha decay of americium–241.

[14] International Commission on Radiological Protection, "Limits for Intakes of Radionuclides by Workers," ICRP Publication 30 (Oxford: Pergamon Press, 1990).

We make the usual assumption that the risk is linear with dose.[15] As a result, independently of whether a total of 1 milligram of PuO_2 is inhaled by 100 people (an average of 0.01 milligrams per person) or by 1,000 people (0.001 milligrams per person) there would be an expected 3–12 cancer deaths as a result.

Dispersal of the Aerosol

For estimating the amount of plutonium aerosol inhaled by the population downwind of a release, one can use a Gaussian plume model (see the appendix) and explore the dependence of its predictions for different assumed meteorological conditions and population distributions. However, in situations like the present one in which the cancer risk is linearly proportional to exposure with no threshold, a much better "feel" for the estimates can be obtained using an extremely simple atmospheric dispersion model, the "wedge" model.[16] The simplicity of the results obtained with this model stem from the fact that, as noted above, for a cancer risk that is linearly proportional to the exposure, the total number cancers in the population downwind will depend only on the total amount of the carcinogen inhaled by the population, not on the distribution of the doses within the population. The accuracy of the predictions of the wedge model is such applications is generally comparable to that of the Gaussian plume model because most of the cancers will ordinarily be due to very small doses at great distances from the release point, where a Gaussian plume assumes a shape approximated by the wedge model.

In the wedge model, the concentration of a contaminant is assumed to be constant in the crosswind direction over the wedge opening angle θ (typically ranging from 0.05–0.3 radians downwind[17]) and in the vertical direction throughout the height H of the mixing layer (typically 300–2,500 meters[18]). Under these conditions, the amount of plutonium inhaled I (in milligrams) by a person a distance r (in meters) downwind is

$$I(r) = \frac{Q(r)b}{\theta r H u} \qquad (1)$$

[15] For a discussion of this approximation, see ***Health Risks of Radon and Other Internally Deposited Alpha-Emitters***, appendix II.
[16] "Report to the American Physical Society by the Study Group on Light-Water Reactor Safety," ***Reviews of Modern Physics*** *47* (1975), p. S45.
[17] ***Reactor Safety Study***, table VI A-1.
[18] Ibid., figures VI A-4 and A-5.

where Q(r) is the amount of plutonium (in milligrams) that remains in the air at distance r downwind, b is the assumed breathing rate ($3.3 \cdot 10^{-4}$ m^3 s^{-1} for an adult male performing light activity),[19] and u is the wind speed (typically between 0.25 and 7 meters per second[20]).[*]

In the absence of rain, the total quantity of airborne material declines with r because of deposition as

$$Q(r) = Q_0 \, e^{-r/L} \qquad (2)$$

where Q_0 is the amount of plutonium released. The average distance an aerosol particle is carried before deposition is

$$L = uH/v \qquad (3)$$

where v is the deposition velocity. For most aerosols, the observed deposition velocities range from 0.001 to 0.1 meters per second.[21] The recommended values for plutonium aerosols from non-nuclear explosions of nuclear warheads is 0.01 meters per second.[22] We will assume a range of 0.003 to 0.03 meters per second. L in the absence of rain therefore can range from tens to thousands of kilometers.

In the presence of rain, there would be an additional exponential term associated with a characteristic washout time constant τ ranging from 10^3 seconds (unstable atmospheric conditions) to 10^4 seconds (stable conditions).[23] The corresponding wet-deposition velocity

$$v_w = H/\tau \qquad (4)$$

is generally much larger than v_d with a range of 0.05 to 1 meters per second. Under rainy conditions, the deposition velocities would be added ($v = v_d + v_w$).

According to the wedge model, the amount of PuO2 inhaled by the total population downwind would be

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[19] ***Health Risks of Radon and Other Internally Deposited Alpha-Emitters***, p. 147. The ratio of breathing rate to lung mass does not vary by more than a factor of two with age (***Reactor Safety Study***, tables IV D-4 and D-5).

[20] ***Reactor Safety Study***, table VI 5-2.

[*] It should be noted that, in principle, it would be possible to reduce considerably the amount of plutonium inhaled if the population stayed inside with windows and air intakes closed during the passage of the aerosol cloud and opened up and aired out the buildings immediately after it had passed. See, for example, Bernard Cohen, ***Health Physics***, Vol. 32 (1977), pp. 359–379.

[21] ***Reactor Safety Study***, table VI B-1.

[22] G.A. Schmel, "Particle and Dry Gas Deposition: A Review," ***Atmospheric Environment***, Vol. 14 (1980).

[23] ***Reactor Safety Study***, appendix VI, p. E-13.

$$I_p = \int_0^{\infty} I(r)\,\theta\, r\, \rho(r)\, dr \qquad (5)$$

where ρ(r) is the population density at distance r downwind averaged over the width of the wedge.

If we assume that the population density is constant, equal to ρ_0, then we find that the total amount of plutonium inhaled is

$$I_p = \frac{Q_0\, b\, \rho_0}{v} \qquad (6)$$

The average population density of the 48 contiguous U.S. states is about 30 per square kilometers; in the most densely populated states of the northeast it ranges around 300 per square kilometer, and 3,000 per square kilometer is a mid-range density for urban areas. For a risk factor of 3–12 cancer deaths per milligram of WgPu inhaled, table 1 shows our resulting estimates of the number of deaths for various combinations of population density and deposition velocity.

It will be noted that in table 1 the entries associated with very low deposition velocity are not filled in for the highest population density. The reasons are that, for v = 0.003 or 0.01 meters per second, L would most likely be hundreds of kilometers—much larger than any urban area.

We have checked the predictions of the wedge model against the corresponding predictions of the Gaussian plume model and obtained quite close agreement, independent of weather conditions.

Table 1. The number of cancer fatalities caused by inhalation during the passage of a plume initially containing 10 kilograms of PuO_2 aerosol for various deposition velocities and average population densities, for a risk factor of 3–12 cancers deaths per milligram of WgPu inhaled.

Deposition velocity	Population density ρ_0 (km^{-2})		
(meters per second)	30	300	3,000
0.003	100–400	1,000–4,000	—
0.01	30–120	300–1,200	—
0.03	10–40	100–400	1,000–4,000
0.1 *rain*	3–12	30–120	300–1,200
1. *rain*	0–1	3–12	30–120

Although the largest entry in table 1—four thousand cancer deaths—is high, the increase in the cancer risk for an individual in the exposed population would be small—typically on the order of one tenth of a percent. For example, for average conditions (H = 1,000 meters, θ = 0.2 radians, u = 2 meters per second, and v = 0.01 meters per second) the additional risk of cancer death would be 0.2–0.9 percent at a distance of 10 kilometers and 0.02–0.06 percent at a distance of 100 kilometers from the release. The small individual risk reflects the fact that the population risk would typically be spread among a very large population. For comparison, the individual cancer death risk in the U.S. is at present about 20 percent. There may well already be many such large-scale cancer "events" occurring in the U.S. due to the widespread release to the environment of carcinogenic chemicals that remain undetected against this large background.[*24]

As an illustrative example, we have estimated the consequences if a hypothetical 10-kilogram release of WgPu aerosol should occur at Bangor Naval Base in Washington state, one of the two bases for U.S. Trident submarines, with the wind blowing towards Seattle. As Bangor is located just 30 kilometers from downtown Seattle, this may represent a near worst case for such an accident. Table 2 gives the radial population density in the direction of Seattle and beyond as a function of distance from Bangor and table 3 gives the wedge-model estimates for the cancer deaths that would result from the release if the wind were blowing in this direction for different combinations of deposition velocity, wind speed and mixing layer height. The average wind speed in Seattle is 4 meters per second, so the average value of Hu is about 4,000 $m^2 s^{-1}$, with a range from about 1,000 to 10,000 $m^2 s^{-1}$. The estimated number of cancer deaths under dry conditions ranges from 20

[*] We note in this connection that approximately 3,000 kilograms of PuO_2 was dispersed into the global atmosphere by atmospheric testing during the later 1950s and early 1960s, about 80 percent of it in the northern hemisphere. The resulting average inhalation by humans in the northern hemisphere was 0.13 nanograms. Using the above total cancer risk coefficients, this translates into an incremental cancer risk of 0.4–1.6 cancers per million persons in the northern hemisphere. Assuming that an average population of 3 billion in the northern hemisphere was exposed to the plutonium fallout (corresponding to an average population density of about 10 per square kilometer), about 1,000 to 5,000 people have died or will die from cancer due to plutonium inhalation, or roughly one person per kilogram of plutonium released.

[24] Four thousand cancer deaths in the lifetime of the U.S. population of 250 million corresponds to an average individual risk of about 10^{-5}. This is in the range where the U.S. Environmental Protection Agency (EPA) tends to set the limits of acceptable risks for the carcinogens that it regulates. [See for example Eliot Marshall, "WPA's High-Risk Carcinogen Policy," ***Science***, Vol. 218 (1982), p. 975.]

to 2,000. These estimates agree well with the prediction obtained using a formula recommended by the Defense Nuclear Agency.*

Table 2. The radial population density in the direction of Seattle from Bangor Naval Base.

Zone	Distance from Bangor (km)	$\rho(r)$ (km^{-2})
Kitsap County	0 – 18	130
Puget Sound	18 – 28	0
Seattle	28 – 38	2300
Lake Washington	38 – 41	0
Bellevue	41 – 50	1200
East suburbs	50 – 70	$1200e^{-0.24(r-50)}$
Mountains	70 – ∞	10

Table 3. Cancer deaths predicted by the wedge model for a 10-kilogram release of WgPu at Bangor Naval Base with the wind blowing towards Seattle.

Deposition velocity v (m/s)	Mixing height · wind speed, Hu ($m^2 s^{-1}$)		
	1,000	3,000	10,000
0.003	400 – 1700	180 – 700	80 – 300
0.01	300 – 1200	150 – 600	50 – 200
0.03	150 – 600	100 – 400	40 – 170
0.1 *rain*	20 – 90	45 – 180	30 – 120
1. *rain*	1 – 5	1 – 5	2 – 9

LAND CONTAMINATION

After the plume passed, it would leave a swath of land contaminated with PuO_2. The main hazard associated with this contamination would be that the plutonium might

* Using a cookbook-style manual written for military commanders to assess the effects of destroying nuclear weapon stockpiles during a war, we have calculated that, over the entire range of meteorological conditions, the number of expected cancer deaths in Seattle alone would be 30–1,000, which compares with then 10–900 cancer deaths given for Seattle by the wedge model. [Field Command, Defense Nuclear Agency, Estimation of the Hazard from Plutonium Dispersal (Kirtland AFB, 1977).]

be resuspended and inhaled. The concentration of the plutonium contamination σ (mg m^{-2}) at a particular point is simply related to the amount I that a person located at that point would have inhaled during the passage of the plume

$$\sigma = vI/b \tag{7}$$

where, once again, v is the deposition velocity (meters per second) and b is the breathing rate ($m^3 s^{-1}$).

The ratio of the concentration of resuspended aerosol to σ can be characterized by a "resuspension coefficient" K. It is therefore easy to make a comparison between the amount of resuspended plutonium inhaled I_r, and I if one knows the resuspension coefficient K (m^{-1}) as a function of time:

$$\frac{I_r(t)}{I} = v\int_0^t K(t')dt' \tag{8}$$

The resuspension coefficient can be expected to decline with time as the plutonium aerosol sinks into the soil and becomes attached to larger particles. Based on a review of the small amount of available data, a 1974 Atomic Energy Commission study suggested for populated areas an initial value $K_0 = 10^{-5}$ m^{-1} declining to a long-term value of $K_\infty = 10^{-9}$ m^{-1}, and interpolated according to the formula

$$K(t) = K_0 e^{-5t} + K_\infty \tag{9}$$

where t is measured in years.[25] Using this function, we find

$$\frac{I_r(t)}{I} = v\left[0.2K_0\left(1 - e^{-5t}\right) + K_\infty t\right] \tag{10}$$

Table 4 shows values of $I_r(t)/I$ calculated for various deposition velocities at 1 month and 1 years (after 1 year the resuspension dose rate will be negligible). Note that resuspension can only be neglected for low to moderate deposition velocities (≤ 0.01 meters per second) and short exposure times (less than a month).

[25] ***U.S. Atomic Energy Agency Proposed Final Environmental Impact Statement Liquid Metal Fast Breeder Reactor Program*** (WASH-1535, 1974), appendix II-G.

Table 4. The ratio of the integrated inhaled dose from resuspension to that from plume passage, for several values of the deposition velocity at 1 month and after 1 year.

Deposition Velocity v (m/s)	Exposure Time, τ	
	1 month	1 year
0.003	0.064	0.19
0.01	0.21	0.63
0.03	0.64	1.9
0.1 *rain*	2.1	6.3
1.0 *rain*	21	63

Evacuation and/or decontamination, as was done at Palomares, could reduce the hazard to that part of the population in the most heavily contaminated area. In most cases, however, virtually all of the population dose would come from a very large area (on the order of 1,000 square kilometers for v = 0.01) of lightly contaminated land that might well be prohibitively expensive to either evacuate or decontaminate. The factors $[1 + I_r(\infty)/I]$ should therefore probably be used to multiply the cancer death estimates in table 1 except for the largest values of v ($\geq$ 0.1 meters per second) and in urban areas where the contaminated areas would probably be decontaminated. Table 5 gives the number of cancer deaths from inhalation during and after the plume passage under these assumptions.

Table 5. The number of cancer fatalities caused by inhalation during the passage of a plume initially containing 10 kilograms of PuO_2 aerosol for various deposition velocities and average population densities, for a risk factor of 3–12 cancers deaths per milligram of WgPu inhaled.

Deposition velocity (meters per second)	Population density ρ_0 (km^{-2})		
	30	300	3,000
0.003	120–500	1,200–5,000	—
0.01	50–200	500–2,000	—
0.03	30–120	300–1,200	1,600–7,000
0.1 *rain*	10–40	100–400	1,000–4,000
1. *rain*	7–30	70–300	700–3,000

CONCLUSION

An accident involving the dispersal of kilogram-quantities of plutonium in aerosol form might, in a worst case (for example, an accident at Bangor Naval Base with the wind blowing toward Seattle with low wind speed and deposition velocity), cause a few thousand cancer deaths during the subsequent decades with a probably undetectable increase in the resulting regional cancer rate. Even under worst-case conditions, no early deaths due to high doses would be expected—certainly not off the base. However, judging from the Three Mile Island and Palomares experiences, the psychological trauma and the costs of reparations and decontaminating the most heavily contaminated areas might be enormous.

To get additional perspective on this risk, let us assume that the probability of a near worst-case accident occurring is 0.1 percent per year.[26] The expected number of deaths would then be on the order of one per year since, under average conditions, on the order of 1,000 cancer deaths would result from a worst-case accident.

This risk could be reduced, but not completely eliminated, by redesigning and rebuilding warheads with IHE—at a cost. A new warhead costs on the order of $1 million and lasts 20–30 years. If old warheads containing sensitive HE were retired an average of 10 years early in order to replace them with warheads containing IHE, the extra cost would be at least $300,000 per warhead. If this were done for the approximately 3,000 warheads that are to be deployed on U.S. submarines after the reductions mandated by START, the cost would be on the order of $1 billion, or $100 million per year of reduced risk. Given that the expected value of the number of lives saved by such an expenditure is on the order of one life or less per year, the resulting cost per life saved would be 250–3,000 times that for other investments in life-saving that the U.S. is currently making.[27]

We therefore conclude that reducing the hazard of plutonium dispersal by converting warheads to IHE need not be dealt with by a “crash” program. However,

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[26] The two large plutonium releases from U.S. nuclear weapons that occurred in the first 50 years of the nuclear age were in areas of low population density, and the practice that resulted in these releases—routine flights by nuclear-armed bombers—has been discontinued.

[27] Bernard Cohen, “Reducing the Hazards of Nuclear Power: Insanity in Action,” Physics and Society, Vol. 16 (1987), p. 2, quotes cost estimates in the range of $20,000–140,000 per life saved for various types of cancer screening, $400,000 for kidney dialysis, and $30,000–300,000 per life saved for various highway improvement programs undertaken by the U.S. Department of Transportation in the early 1980s.

for warheads that a government expects to replace upon their retirement, it would be desirable to have available replacement designs containing IHE. If such designs are not available already, their development should be given priority in any further testing before the achievement of a comprehensive test ban.

Another hazard that has been hinted at in the recent press stories on warhead safety is that, under certain conditions, detonation of the chemical explosive in a warhead might result in a nuclear yield greater than 4 pounds of TNT equivalent. Specifically, there is apparently concern that this might occur in case of near-simultaneous explosions of the HE in the W88 warheads of a Trident-II missile, which are closely clustered around the third-stage rocket motor.[28] It is difficult for us to provide any perspective on this concern in the absence of public estimates of the size of the nuclear yield that might result in such an event.

Appendix
THE RISK OF HIGH-DOSE EFFECTS

Health Effects at High Doses

Because it is relatively insoluble, a substantial fraction of inhaled PuO_2 will remain in the lungs for a long time. Early effects are therefore dominated by damage to lung tissue.

Experiments with beagle dogs indicate that, if a relatively large amount of aerosol were inhaled, the lung damage from the resulting alpha irradiation would cause death from acute respiratory failure within a week. This would occur for an initial alveolar deposition of about 60 micrograms of $^{239}PuO_2$ per gram of bloodless lung,[29] which corresponds to a total inhalation of about 100 mg of weapon-grade plutonium (WgPu) by an adult human.[30]

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[28] R. Jeffrey Smith, "Defective Nuclear Shells Raise Safety Concerns," ***Washington Post***, 23 May 1990, p. A-1.

[29] W.J. Bair, J.E. Ballou, J.F. Park, and C.L. Sanders, "Plutonium in Soft Tissues with Emphasis on the Respiratory Tract," in H.C. Hodge, J.N. Stannard, and J.B. Hursh, eds., ***The Handbook of Experimental Pharmacology, Vol. 36: Uranium-Plutonium-Transplutonic Elements*** (New York: Springer-Verlag, 1973), p. 548.

[30] The specific alpha activity of fresh weapon-grade plutonium (6 percent plutonium-240) is 72.5 microcuries per milligram—1.17 times that of plutonium-239. The bloodless lung of man weighs about 500 grams. The fraction of inhaled material initially deposited in the alveoli ranges from 5 to 50 percent for aerosols with a mass median aerodynamic diameter (MMAD) of 10 to 0.2 microns; for an MMAD of 1 micron, the fraction is 25 percent. Thus, 100 milligrams of WgPu inhaled is equivalent to an alveolar deposition of 0.06 milligrams of plutonium-239 per gram of bloodless lung. In a human being, about 60 percent of this deposition would remain in the lung with a retention half-life of 1.4 years.

The same set of experiments with dogs indicates that, at lower doses, death occurs later because of respiratory insufficiency resulting from extensive fibrosis. The deposition of 2 micrograms of $^{239}PuO_2$ per gram of bloodless lung (corresponding to the inhalation of about 3 milligrams of WgPu by an adult human) will result in death within several months.[31] At still lower doses, fibrosis develops more slowly. A least-squares fit to the relationship between Y, the initial alveolar deposition in micrograms of plutonium-239 per gram of lung and t, the average length of time in days before the deaths of dogs given that dose is[32]

$$Y = 560\ t^{-1.028} \qquad (11)$$

At the maximum lifetime of a beagle (15 years) this relationship gives an alveolar deposition of 0.09 micrograms of $^{239}PuO_2$ per gram of bloodless lung. (This also happens to be the lowest dose at which a dog died of fibrosis in the experiment.)

Pulmonary neoplasia (a cancer) began to occur in dogs that survived 3 to 5 years after exposure in these experiments and was the cause of death in exposed dogs that survived more than 5 years. The least-squares fit to the dose-longevity curves for dogs dying of neoplasia is[33]

$$Y = 11{,}000\ t^{-1.416} \qquad (12)$$

This curve intersects the maximum beagle lifetime at Y = 0.04 micrograms per gram, which corresponds to a inhalation of about 0.08 milligrams of WgPu by an adult human.

Dispersal of the Aerosol at Short Distances

The inhalation high doses that are the subject of this appendix would occur, if at all, close to the release where the approximations made to obtain the wedge model would not hold. For the purposes of estimating high-dose health effects from an accident we have used a Gaussian plume model to estimate the dispersal of plutonium at short distances. In this model, the time-integrated ground-level concentration of plutonium (mg s m^{-3}) downwind from the release is given by

[31] The dose-mortality curve in Bair, et al., "Plutonium in Soft Tissues," p. 548, gives an initial alveolar deposition of 2 micrograms per gram for a survival time of 6 months, which corresponds to an adult inhaling 3 milligrams of WgPu.
[32] Ibid., p. 548.
[33] Ibid.

$$\chi(x, y) = \frac{Q(x)}{\pi \sigma_y \sigma_z u} \exp\left[-\frac{y^2}{2\sigma_y^2} - \frac{z^2}{2\sigma_z^2} \right] \quad (13)$$

where x is the downwind distance and y is the crosswind distance (m), Q(x) is the mass (milligrams) of plutonium aerosol remaining in the cloud when it arrives at x, σ_y and σ_z are the horizontal and vertical standard deviations of the cloud concentration at point x, u is the mean wind speed (m/s), and h is the centerline height of the cloud. Formulae for σ_y and σ_z for a point source are given in the ***Reactor Safety Study*** for atmospheric conditions ranging from very unstable (class "A") to very stable (class "F");[34] we have modified these formulas so that they give the initial standard deviations of the explosion-formed cloud, σ_y^0 and σ_z^0, at x = 0, and so that they are appropriate for an instantaneous (rather than a continuous) release. Since the mixed layer of atmosphere normally has a finite height H (typically 300 to 2,500 meters), we have also modified equation 13 to prevent plutonium from diffusing above the mixed layer and to account for reflections from the top of the mixed layer and the ground.

The amount of plutonium remaining in the cloud at distance *x* is given by

$$Q(x) = Q_0 \exp\left[-\sqrt{\frac{2}{\pi}} \frac{v}{u} \int_0^x \frac{dr}{\sigma_z} e^{\frac{-h^2}{2\sigma_z^2}} \right] \quad (14)$$

where Q_0 is the initial amount of plutonium in the cloud (mg) and v is the deposition velocity of the aerosol (m/s). As mentioned above, a worst-case accident might involve the detonation of the HE in several ballistic-missile warheads (and perhaps the missile propellants as well), releasing as much as 10 kg (10^7 mg) of WgPu as respirable particles. As noted above, depending on the size and composition of an aerosol, v can range from 0.001 to 0.1 m/s; a typical value for plutonium is 0.01 m/s.

The initial height (h) and size (σ_y^0 and σ_z^0) of the cloud depends on the amount of explosive energy released. (Cold, ground-level releases from smoldering chunks of plutonium are not considered credible.[35]) Since reentry vehicles typically weigh 100 to 200 kg, warheads probably contain 20 to 50 kg of HE. Since normal HE is nearly twice as energetic as TNT, an accident could result in an explosion

[34] ***The Reactor Safety Study***, table VI A-1.
[35] ***Report on the Safety Criteria for Plutonium-Bearing Nuclear Weapons***, Appendix, p. 28.

equivalent to between 40 and more than 400 kg of TNT, depending to the number of warheads involved. The detonation of the propellants in the third stage of a missile would be equivalent to an additional 4 to 8 tons of TNT.[36] Estimates of the initial cloud heights and radii for low, medium, and high energy releases are given in table 6.[37] As else being equal, smaller explosions are more dangerous because the plutonium-bearing cloud remains closer to the ground.

Table 6. Cloud-top height and mean radius in meters for low, medium, and high energy releases from an accident involving the detonation of the HE in one or more nuclear weapons and possibly the third stage of a ballistic missile as well.

Estimate	Yield (kg TNT)	Cloud-top height (m)	Mean radius (m)
Low	40	230	19
Medium	400	410	44
High	4,000	740	110

Experiments have shown that approximately 5 percent of the radioactivity in the cloud is initially found between the ground an T/4, where T is the cloud-top height; 30 percent between T/4 and T/2; 40 percent between T/2 and 3T/4; and 25 percent between 3T/4 and T. We have modeled this situation by using four cloud sources containing the above fractions of plutonium with centerline heights of T/8, 3T/8, 5T/8, and 7T/8; σ_y^0 of R/4, R/3, R/2, and R/2, where R is the initial cloud radius; and σ_z^0 equal to T/8.[38]

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[36] Assume a third stage carrying ten warheads weighing 100 to 200 kilograms each gives them a velocity increment of 2.5 kilometers per second. Also assume that the post-boost vehicle (including propellants) weighs as much as the warheads, and that the total stage mass is 1.1 times the propellant mass. Then, using the rocket formula, the propellant mass in the third stage would be equal to $(e - 1)\cdot 2\cdot 10/(1.1 - 0.1e) = 40$ times the mass of a single warhead, or 4 to 8 tonnes in all.

[37] H.W. Church, Cloud Rise from High Explosive Detonations (Albuquerque, NM: Sandia National Laboratory, report TID-4000, UC/41, 1969), gives the following formulas for the cloud-top height T and the cloud radius R: $T = 76W^{0.25}$, and $R = 3.5W^{0.375}$, where T and R are in meters and W is in pounds of TNT equivalent.

[38] ***Supplementary Documentation for Environmental Impact Statement Regarding the Pantex Plant: Dispersion Analysis for Postulated Accidents***, LA-9445-PNTX-D (Los Alamos, NM: Los Alamos National Laboratory, 1982).

The amount of plutonium that would be inhaled by an individual (in milligrams) standing on open ground is given by

$$I(x,y) = \chi(x,y)b \qquad (15)$$

where b is the breathing rate (m^3/s). As noted above, for an adult male performing light activity, b = 20 liters per minute = $3.3 \cdot 10^{-4}$ m^3 s^{-1}.

Table 7 gives the results of the Gaussian plume model for a 10-kilogram release of WgPu under conditions that result in the highest doses to individuals (u = 1 m/s, H = 300 m) for unstable, stable, and neutral conditions.[39] A maximum dose approaching 0.08 milligrams—the lowest dose likely to cause threshold effects—occurs only at close ranges (< 500 meters) and low wind speeds (≤ 1 meter per second). Therefore doses exceeding 0.08 milligrams are highly unlikely to occur anywhere near civilian populations.

Table 7. The amount of plutonium inhaled by an individual (milligrams) during the plume passage at several points downwind on the plume centerline for unstable, neutral, and stable conditions, under worst-case assumptions about wind speed (u = 1 meter per second), plume height (40-kilogram equivalent TNT explosive energy release) and thickness of the mixed layer (H = 300 meters).

Distance down-wind (km)	Dose (milligrams) unstable	neutral	stable
0.1	0.08	0.07	0.08
0.2	0.1	0.06	0.06
0.5	0.07	0.04	0.05
1	0.03	0.03	0.03
2	0.02	0.02	0.02
5	0.003	0.014	0.011
10	0.002	0.011	0.006

39 The dose at a given point is approximately inversely proportional to u and, at distances of less than 10 kilometers, is relatively insensitive to factor-of-ten increases in v and H.

Summary

If the area around the release is evacuated after the plume passes to avoid chronic exposure to deposited plutonium, there will almost certainly be *no* acute health effects from a worst-case accident, even close to the site and under worst-case weather conditions. This is especially true of civilian populations, which are usually no closer than a few kilometers from locations where missiles or nuclear weapons are loaded or stored. Even if the surrounding population was *not* evacuated and the land was *not* decontaminated for long periods of time (conditions that are highly unlikely), the maximum off-site dose would exceed 0.08 milligrams only under a very limited set of weather conditions combined with a very low cloud height. Therefore, for all practical purposes, threshold health effects from such accidents can be ignored.

DOE/EIS-236-S2

U.S. Department of Energy

Draft Supplemental Programmatic Environmental Impact Statement on Stockpile Stewardship and Management for a Modern Pit Facility

Summary

May 2003

U.S. Department of Energy
National Nuclear Security Administration

Pit capacity requirements must also account for the need for additional pits, e.g., logistics spares and surveillance units. As a result of this requirement, the number of pits that must be available to support a specific weapon system will exceed the number of deployed strategic weapons and vary by pit type.

Contingency production requirements are also an important driver for the need for a MPF. Contingency production, which is the ability to produce a substantial quantity of pits on short notice, is distinct from the capacity needed to replace pits destroyed for surveillance or other reasons (such as for production quality assurance or other experiments). The capacity of a MPF needs to support both scheduled stockpile pit replacement at EOL and any "unexpected" short-term production. Such short-term "contingency" production may be required for reliability replacement (replacement of pits to address, for example, a design, production, or unexpected aging flaw identified in surveillance), or for stockpile augmentation (such as the production of new weapons, if required by national security needs).

In all cases, and in all combinations with other capacity drivers, the interim production capacity being established at LANL will be inadequate to maintain these projected stockpiles. The required production capacity is a function of pit lifetime, stockpile size, and start date of full-scale production. To account for these variables, this MPF EIS evaluates a pit production capacity between 125-450 ppy for full-scale production beginning in approximately 2020.

S.2.1.4 Agility as a Driver

A critical element of production readiness is the agility (the ability to change rapidly from the production of one pit type to another, or to simultaneously produce different pit types) of the production line. Pits in the current enduring stockpile were produced over a relatively short period of time and can therefore be expected to reach their respective EOLs at about the same time, as well. Thus, any strategy to replace the enduring stockpile pits before they reach their EOL must address both the production rate for a particular pit type (the capacity driver discussed in Section S.2.1.1), and the ability to produce all necessary pit types in a relatively short period of time. For this reason, agility is an essential requirement for a MPF.

Contingency production also requires agility. If contingency production is ever needed, the response time will likely be driven by either a reliability problem that requires prompt response, or another type of emergency that must be addressed quickly. Thus, changeover from production of one pit type to another will have to be demonstrated for both replacements of pits at EOL (a process that will allow for planning and scheduled activities in advance of the need date), as well as for startup of contingency production with little notice (and therefore little planning time).

S.2.2 Purposes to be Achieved by a Modern Pit Facility

If constructed and operated, a MPF would address a critical national security issue by providing sufficient capability to maintain, long-term, the nuclear deterrent that is a cornerstone of U.S. national security policy. A MPF would provide the necessary pit production capacity and agility that cannot be met by pit production capabilities at LANL.

Department of Energy
National Nuclear Security Administration
Washington, DC 20585

November 28, 2006

OFFICE OF THE ADMINISTRATOR

The Honorable John Warner
Chairman
Committee on Armed Services
United States Senate
Washington, DC 20510

Dear Mr. Chairman:

The Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005 directed the Administrator of the National Nuclear Security Administration (NNSA) to enter into a contract with a Federally Funded Research and Development Center (FFRDC) providing for a study to assess the efforts of the NNSA to understand the aging of plutonium in nuclear weapons. The enclosed report by the independent JASON group reviewing the studies conducted by the Los Alamos and Lawrence Livermore National Laboratories meets this requirement. The JASON review provided an independent evaluation of the scientific credibility of the laboratory studies. The weapon lifetimes are determined by the laboratories.

The studies conducted by the laboratories included an extensive experimental and computational investigation of the mechanical, physical, and chemical property changes caused by plutonium aging as well as a re-analysis of the underground nuclear test record. The results of these studies were incorporated into system-specific performance models that evaluated the effect of these property changes on primary performance, using the Quantification of Margins and Uncertainties methodology. The conclusion of the JASON report is that most plutonium pit types have credible lifetimes of at least 100 years. Other pit types have mitigation strategies either proposed or being implemented. Overall, the studies showed that the majority of plutonium pits for most nuclear weapons types have minimum lifetimes of at least 85 years.

Based on our current analysis and knowledge, changes due solely to plutonium aging do not prevent significantly longer pit lifetimes for warheads with sufficient margins. Mitigation strategies to address systems with tight performance margins are being proposed that do not require replacing current pits or nuclear testing. We can, therefore, conclude that pit lifetimes do not at present determine warhead lifetimes.

It is imperative that we continue to assess plutonium aging through vigilant surveillance and scientific evaluation, since the plutonium-aging database only extends to approximately 48 years for naturally aged material and 60 years for the accelerated aged material. The primary performance database from underground testing is even more limited. The laboratories will annually re-assess the primary performance lifetimes that result from plutonium aging by incorporating new data, understanding, and predictive capabilities as they become available. This is now part of the annual assessment process for each weapon system, which uses all of the stockpile stewardship tools, including aging assessments, to determine the condition of the stockpile.

The unclassified edition of the report from JASON is submitted with this letter. The complete reports from both laboratories and JASON are classified and are submitted separately.

If you have any questions, please contact me or C. Anson Franklin, Director, Office of Congressional, Intergovernmental and Public Affairs at (202) 586-8343.

Sincerely,

Linton F. Brooks
Administrator

Enclosure

cc:
The Honorable Carl Levin
Ranking Minority Member

Pit Lifetime

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JSR-06-335

November 20, 2006

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Contents

1 EXECUTIVE SUMMARY

JASON reviewed the nearly-completed assessment of primary-stage "pit" lifetimes due to plutonium aging for nuclear weapon systems in the enduring U.S. stockpile. The assessment is being prepared by Los Alamos and Lawrence Livermore National Laboratories in support of NNSA's "Level-1" milestone to understand possible aging effects in the primary stages of nuclear weapons in the current stockpile and to provide system-specific lifetimes for pits. The joint Laboratory assessment uses the methodology of Quantification of Margins and Uncertainties (QMU) and specifically considers the physical aging effects of plutonium.

We judge that the Los Alamos/Livermore assessment provides a scientifically valid framework for evaluating pit lifetimes. The assessment demonstrates that there is no degradation in performance of primaries of stockpile systems due to plutonium aging that would be cause for near-term concern regarding their safety and reliability. Most primary types have credible minimum lifetimes in excess of 100 years as regards aging of plutonium; those with assessed minimum lifetimes of 100 years or less have clear mitigation paths that are proposed and/or being implemented.

The Laboratories have made significant progress over the past 3-5 years in understanding plutonium aging and pit lifetimes. Their work is based on analyses of archival underground nuclear-explosion testing (UGT) data, laboratory experiments, and computer simulations. As a result of the Los Alamos/Livermore efforts, JASON concludes that there is no evidence from the UGT analyses for plutonium aging mechanisms affecting primary performance on timescales of a century or less in ways that would be detrimental to the enduring stockpile. The detailed experiments and computer simulations performed by the Laboratories to better understand plutonium aging mechanisms and their possible impact on performance of weapons primaries also reduce uncertainties in the expected performance of zero-age pits. The plutonium aging studies are therefore valuable to the overall Stockpile Stewardship program.

JASON identified additional work that should be carried out over the next year or longer to gain a better understanding of relevant plutonium properties and aging phenomena that could affect weapons performance on timescales of a century and beyond.

A more detailed version of this Executive Summary appears in the full (classified) JASON Report.

2 INTRODUCTION

Los Alamos National Laboratory (LANL) and Lawrence Livermore National Laboratory (LLNL) have been tasked by the National Nuclear Security Administration (NNSA) to "provide estimates for predominant pit types" in a Level 1 Milestone Report by September 30, 2006. Results of this assessment by the two nuclear weapons design laboratories could have significant implications for the scope and timing of proposals to restore U.S. capability to manufacture replacement pits. It is therefore important to provide scientifically credible information about pit lifetimes to the decision makers at NNSA. JASON was asked to conduct a comprehensive review of the pit assessment programs of the Laboratories as they approach this Milestone.

Previously, JASON conducted preliminary studies of specific elements of the work of the Laboratories on pit aging. Our studies began with briefings on pit lifetimes presented to JASON by LANL and LLNL in July 2004, briefings in January 2005, a review of the use of underground test (UGT) data in pit lifetime estimates in January 2006, and a followup meeting on the statistical analysis used in April 2006. The findings and recommendations of these earlier phases of the study have been published in classified JASON reports. The final phase of the review was based on briefings that took place in June 2006, two months before the deadline for the Milestone Report. The Laboratory scientists described to JASON their procedures and the majority of their pit lifetime estimates for specific weapons systems.

The purpose of the overall study is to determine whether the research done by the laboratories is adequate to support a reliable pit lifetime assessment for specific systems. Three kinds of research have contributed to the programs of the two Laboratories. The first consists of analysis of results of past underground tests (UGTs) with pits of various ages. Second are studies of the component materials, including experimental and theoretical investigations of the metallurgical properties of Pu containing various combinations of impurities. The experiments involve small-scale (e.g., static compression), medium-scale (e.g., gas-gun dynamic compression), and larger-scale (e.g., hydrotest and sub-critical) experiments. Third are computer simulations of primary performance with model Pu properties varying with age.

JASON was asked by NNSA to consider the following questions:

1. Have the Laboratories identified relevant properties of plutonium, which when varied have significant impact on primary performance? Is this program of research adequate to quantify, bound or, where possible, reduce associated uncertainties? Have appropriate priorities been established?

2. Will the current program of research serve to assess the impact of aging on the properties of plutonium in a reasonably complete and technically sound manner? Will the proposed experiments have the accuracy required to reduce or bound uncertainties? Is the balance amongst activities and program prioritization appropriate?

3. Is the accelerated aging program appropriate and technically sound? Will the planned activities confirm that the accelerated aging samples adequately replicate the properties of naturally aged plutonium and provide a credible extrapolation beyond the age of existing stockpile materials?

4. Are the Laboratories pursuing a program of research for model development and simulation of fundamental plutonium properties and their change with age that will provide useful information in the required time frame?

5. Have the Laboratories provided a scientifically valid and defensible pit lifetime for each of the systems analyzed?

6. Are there areas of uncertainty identified where additional work should be focused?

Questions (1)–(4) were answered in our two previous reports: generally in the affirmative, albeit with a number of recommendations for changing details of the program (to which the Laboratories have been responsive). This report is therefore mainly concerned with questions (5) and (6). Our answers to both of these questions are summarized in the Executive Summary and explained in detail in the body of the report.

3 UNDERGROUND TEST DATA

To adduce evidence for aging, the Laboratories have carried out a detailed examination of the legacy underground test (UGT) data. Though the data are remarkably precise (some critical parameters measured to 1-3%), measurement accuracies were not uniform in time, and accurate errors needed to be established. We conclude that the Laboratories have extracted all possible information regarding pit aging from the UGT data given the uncertainties associated with those data.

4 PLUTONIUM PROPERTIES

Plutonium is a remarkable material. In an electronic sense Pu exists on the knife-edge between localized and delocalized behavior, and these electronic characteristics in part give rise to extensive polymorphism as a function of temperature, pressure, and composition. The δ-phase of Pu stabilized with Ga in the face-centered cubic structure is used in most pits. Pu undergoes radioactive decay and self-irradiation, which causes build-up of Am, U, and Np, and in addition, He bubble formation. These radiation-induced changes lead to complex defects and microstructure. Compounding the problem is the fact that the δ-Pu alloys of interest are unstable under ambient conditions and can partially transform to new phases and phase segregate. Despite these effects there is substantial lattice annealing that counteracts this damage. Indeed, an important finding is that despite the self-irradiation, δ-Pu alloys are remarkably resilient and maintain their integrity (e.g., not undergoing void swelling as discussed below). The question at hand is how changes in physical and chemical properties affect pit performance and on what time scale.

Research on how material properties change with age includes laboratory experiments and computer simulations. Most of the focus has been on Pu and pits. Experiments and calculations on actual and simulated pit materials are combined with experiments on ^{238}Pu-spiked material in accelerated aging experiments. However, the high explosive and other components also need attention. We have reviewed much of the program on pit-material aging in our previous reports, and do not repeat that discussion here. New developments have emerged in the past year, including results published in the open literature.

4.1 Ambient Condition Studies

The best-understood part of Pu aging is the change in its isotopic and elemental composition as unstable isotopes decay. Because half-lives are known very accurately, and relevant cross-sections are generally well known, the contribution of radioactive decay to aging may be calculated with confidence. At early times the dominant contribution is the decay of ^{241}Pu (about 0.5% of pit alloys) with a half-life of 14.4 years to ^{241}Am, which has a lower fission cross-section. At later times, following the depletion of the ^{241}Pu, the rate of decrease resulting from the decay of ^{239}Pu, ^{240}Pu and ^{241}Am is a few times less. If there were no other relevant aging processes these values would themselves imply lifetimes, depending on the margin, of several hundred to over a thousand years.

Surveillance of pits and laboratory experiments on Pu alloys provide direct information on changes in physical and chemical properties with age. Considerable work on density changes in Pu alloys due to aging has been done using volumetric, dilatometric and x-ray diffraction techniques. The results, which were reviewed during the past year, have clarified several inconsistencies. Much of this work involves standard microanalysis, including optical and electron microscopies, and has benefitted from the Enhanced Surveillance and Dynamic Material Properties Campaigns.

The Pu accelerated aging program augments the study of naturally aged Pu. A central question is the extent to which these "artificially" aged samples are representative of "naturally aged" material, given the differences in isotopic composition and heating. A variety of measurements demonstrate qualitative similarities between the two types of material. The samples are held at different ambient temperatures in order to try to match annealing effects. There are also similarities in the density and strength changes. Differences due to the isotopic distribution are well accounted for.

Ga-stabilized δ-Pu is metastable at room temperature. Many of the issues that arise are related to the metastability of the δ-Pu alloy and the nearly 20% volume difference between the δ and α phases. The potential consequences of the thermodynamic metastability for aging of δ-phase alloys have been examined experimentally for both naturally and artificially aged material. Phase decomposition and segregation can occur but the kinetics are slow, with little loss in integrity of the bulk material.

4.2 Equation of State

The equation of state (EOS) is the fundamental thermodynamic relation between the density, pressure, temperature, and composition, and therefore includes the zero-pressure density and compressibility. At least approximately, the measurements between methods and between naturally and accelerated-aged Pu are consistent.

Theoretical calculations are in principle capable of disentangling the separate effects of lattice damage, interstitial and bubble He and chemical impurities and of surveying the entire $P-V$ plane, on and off the Hugoniot. These calculations are generally limited to small simulation cells, while phenomenological calculations are subject to uncertainties in the interatomic potentials. Differential effects of aging may be estimated to useful accuracy even if the absolute accuracy is limited.

There is a need to extend high level computations to the actual performance of aged Pu. LLNL and LANL have both applied large-scale molecular dynamics codes to attempt to simulate the effect of shock compression. This work has been performed on the BlueGene/L supercomputer for various metals. It is important to continue to improve high level calculations on Pu using multiscale modeling approaches, as discussed below.

4.3 Void Swelling

One of the major concerns initially in Pu aging was the possibility of void swelling. Void swelling is a well-known consequence of radiation damage in nuclear reactor material. Because of the potential expansion of material with void swelling, it has been a serious concern. However, there is no empirical evidence for void swelling in aged δ-Pu. This, in itself, is reassuring because in other materials void swelling begins gradually after a finite incubation time, and phenomenological estimates based on these data indicate that any void swelling in δ-Pu will not be significant for several more decades. Even more reassuring is the theoretical expectation that δ-Pu will not undergo void swelling at all. This follows from the fact that the calculated volume increase produced by an interstitial atom in δ-Pu is less (in magnitude) than the calculated volume decrease produced by a vacancy (in materials known to undergo void swelling the inequality is in the opposite direction). This implies that radiation damage will not tend to produce net strain that can be relieved by nucleating a void. Qualitatively, this is expected because δ-Pu has an expanded structure, so that disturbing it will tend to reorganize it in the direction of the denser α phase rather than expanding it. Nucleation of a δ to α transition is prevented by the presence of the stabilizing Ga, which is redistributed by radiation damage so that it is not lost to isolated regions of Pu_3Ga, as would be required for such a phase transformation. In view of the importance of possible void swelling in Pu phases, fundamental studies of the problem should continue, for example using accelerated aged material.

4.4 Strength

Strength is not an equilibrium thermodynamic property and is dependent on many factors. At the outset, it is important to distinguish between different types and measures of strength. These types include compressive yield strength, shear strength, and tensile strength. All are in general strongly dependent on temperature, strain rate, and phase, and can differ for single crystals, polycrystalline aggregates and composites. Thus, the strength of Pu at very high rates of deformation may be different from that observed in static or low strain-rate measurements.

Measurements on Pu at low strain rates show increases in strength with age, either natural or accelerated. This is found both for yield strength (the tensile stress at which irreversible plastic work begins, usually defined at 0.2% strain) and for ultimate tensile strength (the maximum stress achieved before a specimen fails, larger than yield strength because of work hardening). However, these measurements of hardness and strength are either static or quasi-static and performed under ambient conditions, rather than those encountered in the implosion of a pit, and their relevance to nuclear performance is at this time unclear.

We commend the approach taken by the Laboratories for investigating strength in order to obtain a conservative estimate of its effects on lifetimes, but potentially larger effects that might act in the opposite direction have not yet been taken into account. We conclude that the Laboratories have made good progress in identifying possible age-related changes to the dynamic strength of Pu, but there is much work to be done to quantify understanding in the regimes most important for pit performance.

5 LIFETIME METHODOLOGY

5.1 QMU Framework

The laboratories have used the methodology of Quantification of Margins and Uncertainty (QMU) to assess pit lifetimes based on simulations of primary performance. Various metrics for this performance have been established but the key requirement is that the primary must produce sufficient nuclear yield to drive the secondary. It is therefore critical to understand if possible degradation of the pit due to Pu aging will ultimately lead to a failure to ignite the secondary. A large series of UGTs have established that the primary will successfully ignite the secondary provided that the yield is sufficiently large. The basic idea is to compute a ratio of the margin M to the total uncertainty U. The higher this ratio, the higher the level of confidence in the weapon's operation, and, in general, a central goal of Stockpile Stewardship is to continually monitor and assess this ratio and to perform mitigation to increase it should the ratio tend close to 1.

Initial minimum credible lifetime estimates provided by the Laboratories serve to highlight when and where more work is needed for a specific primary system. The non-uniqueness of defining a lifetime for a low margin system is shown by the following. The physics input leads to M and U changing with time as:

$$M(t) = M_0 + St \qquad U(t)^2 = U_0^2 + (\delta S)^2 t^2$$

where we assume that changes are described by a linear slope, S, with an error δS (2σ, to be consistent with U as discussed above), and

$$(\delta S)^2 = \sum_i (\delta S_i)^2$$

Yearly certification demands that $M > U$, so the lifetime T is defined by

$$M(T) = U(T).$$

The determination of lifetime T for then depends on knowing four numbers, M_0, U_0, S, and δS. We have two limiting cases:

1. When the effect of aging is well understood and can be calculated accurately:
$$\delta S \ll S \Rightarrow T \approx \frac{M_o - U_o}{S}$$

2. When the effect of aging has large uncertainty and M_o is not very close to U_o:
$$\delta S \gg S \Rightarrow T \approx \sqrt{\frac{M_o^2 - U_o^2}{(\delta S)^2}}.$$

For systems with low margins, $M_o \approx U_o$ and hence different approaches to error handling will give different answers. These considerations point to the need for continued work on assessment of margins and uncertainties.

6 BEYOND THE LEVEL 1 MILESTONE

The Laboratories have made significant progress toward meeting the Level 1 Milestone, exceeding requirements in some ways, but also identifying work that remains to be done. Although more work is needed, both to provide more complete validation of the lifetime estimates themselves, and to better determine the associated uncertainties and tradeoffs (e.g., mitigation strategies), it is likely that the overall level of effort required is much less than in the past 3–5 years. Another key reason for further work is to gain experience with Pu that has suffered the equivalent of a century or more of aging (i.e., with accelerated aging), thereby allowing an interpolation rather than an extrapolation in estimating performance changes and degradation due to aging. In particular, one wants to know the modes of failure that will be among the first to appear, because these can inform the stockpile surveillance program in order to make it most sensitive to aging-induced degradation.

The following is a listing of recommendations for follow-on studies, with a justification for the need and prioritization (or scheduling) of each recommendation.

1. *Validation through peer review of current estimates of primary-performance lifetimes.* Several systems require more detailed analysis in order to obtain reliable estimates of minimum lifetimes, and their associated uncertainties and tradeoffs. For these systems it is important that each contribution to the lifetime be well understood and validated. In a sense, the issue is not one of accounting for aging but of managing the margins and uncertainties that are already present at zero age, and this is best done by understanding the tradeoffs involved and the consequent mitigation strategies that can be applied. It is our highest-priority recommendation that this effort be completed within a matter of several weeks in order to ensure that no problems remain unrecognized with the current level of analysis. (We note that this short term recommendation has largely been completed since

the writing of this report.)

2. *Primary performance and material strength.* There must be a more detailed understanding of the different types of dynamic (high strain-rate) strengths involved in the weapons codes, and then a more complete understanding of how these strengths vary with aging through relevant experimental and theoretical work. This is fundamentally difficult because strength is not an equilibrium-thermodynamic property, so is not well defined theoretically nor is it always well-defined experimentally. Moreover, the relevant regimes of high pressures, temperatures and strain rates are difficult to access, and the loading-path history and associated kinetics across the material phase diagram are therefore not well determined. New experiments should be carried out on both naturally and artifically aged Pu.

3. *Extended accelerated aging experiments on plutonium.* These include both ongoing study of the current accelerated-aging Pu samples, which are spiked with the rapidly-decaying ^{238}Pu, as well as production of samples that have been aged by alternative means. In all of these cases, the objective is to get the equivalent of multi-century experience on aging phenomena, associated with decay (e.g., radiation damage) as well as with activated processes such as annealing. The latter requires taking sub-samples of accelerated-aged material through various temperature cycles in order to determine how the activated processes have been affected by radioactive decay. This is longer-term (multi-year) work both because time is required for the samples to reach appropriate (equivalent) ages, and because one is looking at effects not likely to influence stockpile weapons for many decades. Nevertheless, such studies are essential in order to validate current understanding, and ensure that no new phenomena lurk unobserved below the surface of existing results, as well as to provide specific predictions of the failure modes to be expected in the stockpile (which in turn inform the surveillance programs on what to look for).

7 FINDINGS AND RECOMMENDATIONS

Our principal findings and recommendations are summarized as follows.

Findings

1. The nuclear weapons design Laboratories have made significant progress in understanding pit aging through improved knowledge of the underlying science and improved techniques for simulating weapons performance. Through their laboratory studies of the materials, including both naturally and artificially aged Pu, and stockpile surveillance activities, the Laboratories have also made significant progress in prioritizing the unresolved questions regarding the aging of stockpile weapons. The labs have also identified key metrics to assess the effects of aging.

2. There is no evidence for void swelling in naturally aged or artificially aged δ-Pu samples over the actual and accelerated time scales examined to date, and good reason to believe it will not occur on time scales of interest, if at all.

3. Systems with large margins will remain so for greater than 100 years with respect to Pu aging. Thus, the issue of Pu aging is secondary to the issue of managing margins.

Recommendations

1. The Level 1 Milestone Report should indicate that the primaries of most weapons system types in the stockpile have credible minimum lifetimes in excess of 100 years and that the intrinsic lifetime of Pu in the pits is greater than a century. Each physical effect on the lifetime of selected systems should be calculated and explicitly reported. The report should emphasize the need to manage margins.

2. Continued work is required beyond the Level 1 Milestone. This includes validating through peer review the current estimates of primary-performance lifetimes for selected primary types, extending accelerated aging experiments on Pu, and determining how aging affects primary performance by way of material strength.

NUCLEAR POSTURE REVIEW REPORT

APRIL 2010

NPR

- The United States will not develop new nuclear warheads. Life Extension Programs will use only nuclear components based on previously tested designs, and will not support new military missions or provide for new military capabilities.

- The United States will study options for ensuring the safety, security, and reliability of nuclear warheads on a case-by-case basis, consistent with the congressionally mandated Stockpile Management Program. The full range of LEP approaches will be considered: refurbishment of existing warheads, reuse of nuclear components from different warheads, and replacement of nuclear components.

- In any decision to proceed to engineering development for warhead LEPs, the United States will give strong preference to options for refurbishment or reuse. Replacement of nuclear components would be undertaken only if critical Stockpile Management Program goals could not otherwise be met, and if specifically authorized by the President and approved by Congress.

- The United States will retain the smallest possible nuclear stockpile consistent with our need to deter adversaries, reassure our allies, and hedge against technical or geopolitical surprise.

Using these guidelines, the United States will extend the life of nuclear warheads required for the smaller force structure identified under New START. Consistent with this approach, the NPR recommended that:

Air Force maintenance technicians work on the B-61 bomb. U.S. Air Force photo.

- The Administration will fully fund the ongoing LEP for the W-76 submarine-based warhead for a fiscal year (FY) 2017 completion, and the full scope LEP study and follow-on activities for the B-61 bomb to ensure first production begins in FY 2017.

- The Nuclear Weapons Council will initiate a study in 2010 of LEP options for the W-78 ICBM warhead to be conducted jointly by the National Nuclear Security Administration and the Department of Defense. This study will consider, as all future LEP studies will, the possibility of using the resulting warhead also on multiple platforms in order to reduce the number of warhead types.

Public Law 110–181
110th Congress

An Act

To provide for the enactment of the National Defense Authorization Act for Fiscal Year 2008, as previously enrolled, with certain modifications to address the foreign sovereign immunities provisions of title 28, United States Code, with respect to the attachment of property in certain judgments against Iraq, the lapse of statutory authorities for the payment of bonuses, special pays, and similar benefits for members of the uniformed services, and for other purposes.

Jan. 28, 2008
[H.R. 4986]

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

National Defense Authorization Act for Fiscal Year 2008.

SECTION 1. SHORT TITLE; TREATMENT OF EXPLANATORY STATEMENT.

(a) SHORT TITLE.—This Act may be cited as the "National Defense Authorization Act for Fiscal Year 2008".

(b) EXPLANATORY STATEMENT.—The Joint Explanatory Statement submitted by the Committee of Conference for the conference report to accompany H.R. 1585 of the 110th Congress (Report 110–477) shall be deemed to be part of the legislative history of this Act and shall have the same effect with respect to the implementation of this Act as it would have had with respect to the implementation of H.R. 1585, if such bill had been enacted.

SEC. 2. ORGANIZATION OF ACT INTO DIVISIONS; TABLE OF CONTENTS.

(a) DIVISIONS.—This Act is organized into three divisions as follows:

(1) Division A—Department of Defense Authorizations.

(2) Division B—Military Construction Authorizations.

(3) Division C—Department of Energy National Security Authorizations and Other Authorizations.

(b) TABLE OF CONTENTS.—The table of contents for this Act is as follows:

Project 08–D–701, Nuclear materials safeguards and security upgrade, Los Alamos National Laboratory, Los Alamos, New Mexico, $49,496,000.

(4) For naval reactors, the following new plant projects:

Project 08–D–901, Shipping and receiving and warehouse complex, Bettis Atomic Power Laboratory, West Mifflin, Pennsylvania, $9,000,000.

Project 08–D–190, Project engineering and design, Expended Core Facility M–290 Recovering Discharge Station, Naval Reactors Facility, Idaho Falls, Idaho, $550,000.

SEC. 3102. DEFENSE ENVIRONMENTAL CLEANUP.

(a) AUTHORIZATION OF APPROPRIATIONS.—Funds are hereby authorized to be appropriated to the Department of Energy for fiscal year 2008 for defense environmental cleanup activities in carrying out programs necessary for national security in the amount of $5,367,905,000.

(b) AUTHORIZATION FOR NEW PLANT PROJECT.—From funds referred to in subsection (a) that are available for carrying out plant projects, the Secretary of Energy may carry out, for defense environmental cleanup activities, the following new plant project:

Project 08–D–414, Project engineering and design, Plutonium Vitrification Facility, various locations, $9,000,000.

SEC. 3103. OTHER DEFENSE ACTIVITIES.

Funds are hereby authorized to be appropriated to the Department of Energy for fiscal year 2008 for other defense activities in carrying out programs necessary for national security in the amount of $763,974,000.

SEC. 3104. DEFENSE NUCLEAR WASTE DISPOSAL.

Funds are hereby authorized to be appropriated to the Department of Energy for fiscal year 2008 for defense nuclear waste disposal for payment to the Nuclear Waste Fund established in section 302(c) of the Nuclear Waste Policy Act of 1982 (42 U.S.C. 10222(c)) in the amount of $292,046,000.

SEC. 3105. ENERGY SECURITY AND ASSURANCE.

Funds are hereby authorized to be appropriated to the Department of Energy for fiscal year 2008 for energy security and assurance programs necessary for national security in the amount of $5,860,000.

Subtitle B—Program Authorizations, Restrictions, and Limitations

SEC. 3111. RELIABLE REPLACEMENT WARHEAD PROGRAM.

No funds appropriated pursuant to the authorization of appropriations in section 3101(a)(1) or otherwise made available for weapons activities of the National Nuclear Security Administration for fiscal year 2008 may be obligated or expended for activities under the Reliable Replacement Warhead program under section 4204a of the Atomic Energy Defense Act (50 U.S.C. 2524a) beyond phase 2A activities.

NUCLEAR MATTERS

A Practical Guide

Foreword

This practical guide to Nuclear Matters is an expanded and revised version of the earlier *Nuclear Weapons Stockpile Management Handbook* and the *Nuclear Weapons Council Handbook*. Originally published in 1991 for the use of Action Officers associated with the Nuclear Weapons Council, previous editions have been modified over time to meet the needs of the larger nuclear weapons community as well as those outside the community who seek a better understanding of the subject. Since the early 1990s, the U.S. Nuclear Weapons Program has evolved significantly as a result of unilateral and bilateral arms reductions and the end of underground nuclear testing in the United States; successive editions of these books have been revised and restructured to reflect these changes.

This book is intended to be an **unofficial** reference that explains the history and development of the U.S. Nuclear Weapons Program as well as the current activities associated with sustaining the U.S. nuclear deterrent. It is designed to be useful, but it is neither authoritative nor directive. Please refer to the applicable statute, regulation, Department of Defense Direction/Instruction, or Department of Energy Order for definitive guidance in all areas related to the U.S. Nuclear Weapons Program.

The content of *Nuclear Matters: A Practical Guide* is the sole responsibility of the Office of the Deputy Assistant to the Secretary of Defense for Nuclear Matters.

Please forward substantive comments and revisions to:

Office of the Deputy Assistant to the Secretary of Defense
(Nuclear Matters)
The Pentagon
Room 3B884
Washington, DC 20301-3050

www.acq.osd.mil/ncbdp/nm

Chapter 2
Life-Cycle of U.S. Nuclear Weapons

2.1 *Overview*

Nuclear weapons are developed, produced, maintained in the stockpile, and then retired and dismantled. This sequence of events is known as the nuclear weapons life-cycle. As a part of nuclear weapons management, the Department of Defense (DoD) and the National Nuclear Security Administration (NNSA) have specific responsibilities related to nuclear weapons life-cycle activities. The life-cycle process details the steps through which nuclear weapons development progress from concept to production to retirement. Figure 2.1 depicts the traditional joint DoD-NNSA Nuclear Weapons Life-Cycle Phases. This chapter describes the most significant activities and decision points of the traditional phases in the life-cycle of a nuclear warhead. The information presented in this chapter is a summary version of the formal life-cycle process codified in the 1953 Agreement.

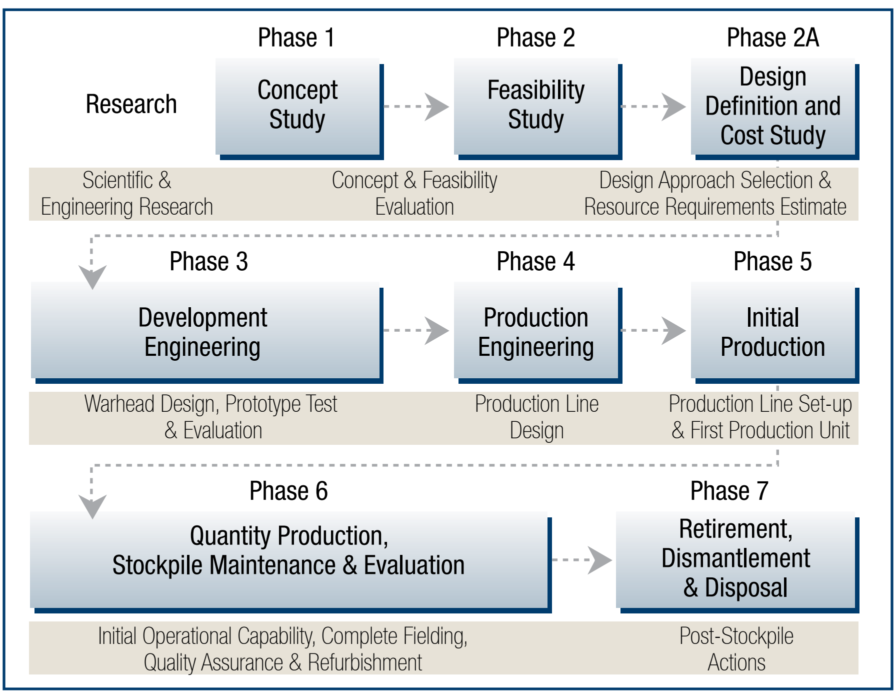

Figure 2.1 Joint DoD-NNSA Nuclear Weapons Life-Cycle Phases

NUCLEAR POSTURE REVIEW REPORT

APRIL 2010

NPR

- The United States will not develop new nuclear warheads. Life Extension Programs will use only nuclear components based on previously tested designs, and will not support new military missions or provide for new military capabilities.
- The United States will study options for ensuring the safety, security, and reliability of nuclear warheads on a case-by-case basis, consistent with the congressionally mandated Stockpile Management Program. The full range of LEP approaches will be considered: refurbishment of existing warheads, reuse of nuclear components from different warheads, and replacement of nuclear components.
- In any decision to proceed to engineering development for warhead LEPs, the United States will give strong preference to options for refurbishment or reuse. Replacement of nuclear components would be undertaken only if critical Stockpile Management Program goals could not otherwise be met, and if specifically authorized by the President and approved by Congress.
- The United States will retain the smallest possible nuclear stockpile consistent with our need to deter adversaries, reassure our allies, and hedge against technical or geopolitical surprise.

Using these guidelines, the United States will extend the life of nuclear warheads required for the smaller force structure identified under New START. Consistent with this approach, the NPR recommended that:

Air Force maintenance technicians work on the B-61 bomb. U.S. Air Force photo.

- The Administration will fully fund the ongoing LEP for the W-76 submarine-based warhead for a fiscal year (FY) 2017 completion, and the full scope LEP study and follow-on activities for the B-61 bomb to ensure first production begins in FY 2017.
- The Nuclear Weapons Council will initiate a study in 2010 of LEP options for the W-78 ICBM warhead to be conducted jointly by the National Nuclear Security Administration and the Department of Defense. This study will consider, as all future LEP studies will, the possibility of using the resulting warhead also on multiple platforms in order to reduce the number of warhead types.

to identifying and responding to potential problems with agility and effectiveness. A strong monitoring program regularly providing comprehensive state-of-the-weapon data is essential to sustain the stockpile. The FY 2012 request supports improved stockpile surveillance activities, including laboratory and component testing for specific weapons systems, support to the annual assessment and certification process, and development of new surveillance techniques. Weapons surveillance activities will ensure early knowledge and understanding of the status of each weapon system and increase the availability of data to aid in that understanding. The enhanced surveillance activities included in the FY 2012 budget will continue the efforts begun in FY 2011 to reposition the nuclear security enterprise to a sustainable surveillance approach for the future.

Many age-related changes affecting various nuclear warhead components are predictable and well understood. Limited life component exchanges are performed routinely to replace these components periodically throughout the lifetime of the weapon. Components such as power sources, neutron generators and tritium reservoirs deteriorate predictably and must be replaced before their deterioration adversely affects function or personnel safety. The NNSA is working with the DoD to align component production requirements with NPR size and composition for the stockpile.

Life extension activities reflect NPR direction. The W76 warhead LEP is well-underway, with first production unit accomplished in FY 2008, and delivery of all units to the Navy to be completed by FY 2017. The B61-12 study to determine the design parameters for its life extension will continue through 2012. This includes consideration of how to modify the Cold War era weapon system for enhanced margin against failure while increasing safety, and improving the security and use control. For example, insensitive high explosives could replace conventional high explosives. Additionally, modifications could be employed to provide greater reliability; and components and materials with known compatibility and aging issues could be replaced, providing better alternatives. With the expected Nuclear Weapons Council (NWC) Phase 6.3 approval in FY 2012, the funding from Stockpile Systems transferred to the LEP subprogram for the B61-12. A life extension study for the W78 is also underway and in order to reduce the number of warhead types it will consider the possibility of developing a common ICBM/SLBM warhead that will include the W88 platform. In all life extension studies, the NNSA will rely on fundamental and applied ST&E to improve its understanding of nuclear weapon behavior, and to assure the safety, security, and effectiveness of our nuclear deterrent supported by a reduced and more sustainable, efficient and appropriately-sized nuclear security infrastructure.

Science, Technology, and Engineering (ST&E)

The Science, Technology and Engineering (Science Campaign, Engineering Campaign, Inertial Confinement Fusion and High Yield Campaign, Advanced Simulation and Computing Campaign) request ensures that we keep the commitment made by President Obama, in his April 27, 2009 address to the National Academy of Sciences, that "Science is more essential for our prosperity, our security, our health, our environment, and our quality of life than it has ever been before…". It is the reality of today's security environment that the United States requires an agile and responsive national security science, technology, and engineering funded enterprise to remain protected from the threats of today and the future. Sustaining the national security ST&E capabilities within the NNSA is important for more than the need to assess and monitor the nuclear weapons stockpile. While national ST&E investments are instrumental in transitioning to a 21st century nuclear deterrent strategy, they are also key to a range of national security issues, tools, and solutions. NNSA and its laboratories have the unique capability to take on complex projects requiring both breadth and depth of science as well as an ability to respond to

NNSA assesses limited life component exchanges for routine maintenance operations and LEPs on major components (i.e., nuclear explosive packages and arming, fuzing and firing components, etc). Both the limited life components and the LEPs rely on the Campaigns for technology maturation to enhance the systems with respect to such issues as safety and use control.

Weapons Systems Cost Data

A classified annex, containing the Selected Acquisition Report for the W76 LEP and, if approved, starting in FY 2012 the B61 LEP, supplements the Weapons Activities portion of the budget.

Annual Performance Results and Targets

The Department is in the process of updating its strategic plan, and has been actively engaging stakeholders including Congress. The draft strategic plan is being released for public comment concurrent with this budget submission, with the expectation of official publication this spring. The draft plan and FY 2012 budget are consistent and aligned. Updated measures will be released at a later date and available at the following link http://www.mbe.doe.gov/budget/12budget/index.htm.

FY 2010 Accomplishments

Life Extension Programs

- Completed 120 percent of Pantex's renegotiated production schedule of the W76-1/Mk4A weapon deliverables to the Navy for the Submarine Launched Ballistic Missiles (SLBM) and 100 percent of negotiated weapon deliveries. The W76-1/Mk4A LEP features include new Arming, Fuzing & Firing Assembly; Cables; 2X Acorn Gas Transfer System (GTS) refurbished Primary and Secondary; and replacement of high explosives and detonators.
- Executed the W76 LEP investments to reduce the risk of production delays. Specifically, certified an alternate material as risk mitigation for Fogbank production and replaced single point failure equipment at the production plants.

Stockpile Systems (B61, W76, W78, W80, B83, W87, W88):

- Delivered all scheduled LLCs (GTS reservoirs and neutron generators (NG)) and alteration kits to the DoD and Pantex to maintain the nuclear weapons stockpile.
- Assessed, as part of the B61-12 life extension study, non-nuclear and nuclear options with Air Force to ensure sustainment of the extended deterrence mission.
- Initiated nuclear technology development efforts and nuclear product realization teams for the B61-12 following approval of the full nuclear scope B61 life extension study reprogramming to ensure study completion remains on schedule.
- Conducted surveillance program via data collection from flight tests, laboratory tests, and component evaluations sufficient to assess stockpile reliability without nuclear testing.
- Completed all Annual Assessment Reports and Laboratory Director letters to the President
- Participated in a DoD led Common Warhead Requirements Working Group/Joint Requirements Working Group for the W78 LEP including the possibility of also using the resulting warhead on SLBMs to reduce the number of warhead types.
- Selected a common NG for the B61 and B83 that will reduce development, production, and maintenance costs.
- Completed planned Phase Gate Reviews (detailed assessments which provide a logical progression of meeting technical and programmatic work requirements and document risk-informed decisions for W87 and B83 NG developments.

Detailed Justification

	FY 2010 Actual Approp	FY 2011 Request	FY 2012 Request
Life Extension Program	**231,888**	**249,463**	**480,597**

Life extension is a major stockpile management program activity NNSA developed to extend the expected stockpile lifetime of legacy weapons systems for an additional 20 to 30 years. The NNSA, in conjunction with the DoD, executes a LEP following the procedural guidelines of the Phase 6.x process. The Phase 6.x process results from NWC recommendations to the President to develop and field replacements for those components that will extend the life of legacy systems and enhance their safety and security. The President then seeks Congressional authorization to expend resources to implement his decisions regarding the options developed during Phases 6.1 (concept assessment) and 6.2 (feasibility and option development). The LEP activities include the research, development, and production work required to ensure weapons systems continue to meet national security requirements.

The production requirements for the B61 and W76 outlined in the 2010 NPR validate a need to continue production ramp up at the Pantex Plant, increase non-nuclear activities at the Kansas City Plant (KCP), and develop advanced surety technologies for the B61, as described in the following narratives on the B61 and W76 LEPs.

▪ **B61 Life Extension Program**	**0**	**0**	**223,562**

The B61 LEP extends the life of the B61 Mod 3, 4, and 7 nuclear bombs. The FY 2012 budget requests funds for the B61 Mod 12 (B61-12) in the LEP control level as activity shifts from a feasibility study to a full LEP. The B61-12 will replace end-of-life components, improve aircraft compatibility, implement improved safety and use control technologies to extend the bomb life for another 30 years. The NNSA plans completion of the First Production Unit (FPU) in FY 2017. The NNSA will deliver the refurbished bomb to the U.S. Air Force for integration with the B-2 Spirit bomber and to U.S. and North Atlantic Treaty Organization (NATO) forces utilizing Dual Capable Aircraft to enable the extended deterrence mission.

The FY 2012 mission scope includes: Phase 6.3 Development Engineering activities for (1) development of designs and continued maturation of technologies for new firing, arming and safing components, radar components, GTSs, NGs, permissive action link components and equipment, power supplies, thermal batteries, joint test assemblies, weapon trainers, and test and handling gear; (2) development of designs and technologies to refurbish the B61 primary with reuse of the existing B61 nuclear pit, reuse or remanufacture of the B61 Mod 4 canned subassembly, and consolidation of the B61 Mod 3, 4, and 7 into a single bomb Mod; (3) pending Phase 6.2 feasibility assessment and down-select decisions, implementation and maturation of enhanced surety technologies into the nuclear explosive package; (4) conduct of qualification and certification activities including component and system testing,

United States Department of Defense

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News Article

U.S. Declassifies Nuclear Stockpile Details to Promote Transparency

By Donna Miles
American Forces Press Service

WASHINGTON, May 3, 2010   The United States released newly declassified details about its nuclear stockpile today, including significant progress made in dismantling warheads, in an effort to promote transparency and help stem nuclear proliferation.

The United States had 5,113 warheads in its nuclear weapons stockpile as of Sept. 30, a senior defense official told reporters today on background.

That represents an 84 percent reduction from the end of fiscal 1967, when the U.S. nuclear arsenal was its largest, with 31,255 warheads, the official said. The current stockpile is 75 percent lower than when the Berlin Wall fell in late 1989, and the United States had 22,217 warheads.

The United States is making continued progress in dismantling nuclear warheads: with 8,748 dismantled between fiscal years 1994 and 2009 and several thousand more currently retired and awaiting dismantlement, the official noted. Meanwhile, the number of non-strategic nuclear weapons in the U.S. arsenal dropped about 90 percent from Sept. 30, 1991, to Sept. 30, 2009.

"For those who doubt that the United States will do its part on disarmament, this is our record, these are our commitments," Secretary of State Hillary Rodham Clinton told the U.N. conference on the Nuclear Proliferation Treaty today in New York. "And they send a clear, unmistakable message."
A senior defense official expressed hope that it would set a standard for the rest of the world, including China, to be more transparent about their nuclear weapons programs.

Clinton said the new Strategic Arms Reduction Treaty with Russia, once approved, will further limit the number of strategic nuclear weapons deployed by both countries to levels not seen

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Clinton also noted that the new Nuclear Posture Review, released in April, rules out the development of new U.S. nuclear weapons and new missions and capabilities for existing weapons. It also prohibits the use of nuclear weapons against non-nuclear weapons states that are parties to the NPT and comply with its nonproliferation obligations.

President Barack Obama has made reducing the threat posed by nuclear weapons and nuclear materials a central mission of U.S. foreign policy, Clinton told the conference.

"I represent a president and a country committed to a vision of a world without nuclear weapons, and to taking the concrete steps necessary that will help us get there," she said. "And, along with my delegation, I come to this conference with sincere and serous proposals to advance the fundamental aims of the NPT and strengthen the global nonproliferation regime."

Although most nations live up to their nonproliferation responsibilities, Clinton said Iran's nuclear weapons ambitions put the entire world at risk and urged the international community to hold it accountable.

She called out Iranian President Mahmoud Ahmadinejad for spewing "the same tired, false and sometimes wild accusations" against the United States and other nations during his address to the assembly earlier today. "Iran will do whatever it can to divert attention away from its own record and … attempt to evade accountability," she said.

Clinton urged Iran to join with other countries represented at the conference to "fulfill our international obligations and work toward the goal of a safer world."

"When President Obama came into office, he recognized that the greatest potential danger facing the United States comes from a terrorist group like al-Qaida obtaining a crude nuclear device, not from a global nuclear war," she said. "The threats of the 21st century cannot be addressed with a massive nuclear stockpile. So we are taking irreversible, transparent, verifiable steps to reduce the number of nuclear weapons in our arsenal."

But in the meantime, Clinton emphasized that the United States won't eliminate all its nuclear weapons until it's safe to do so. "The United States will maintain a nuclear deterrent for as long as nuclear weapons exist, one that can protect our country and our allies," she said.

The U.S. nuclear stockpile includes both active and inactive warheads, defense officials explained. Active warheads include strategic and non-strategic weapons maintained in an operational, ready-for-use configuration, warheads that must be ready for possible deployment within a short timeframe, and logistics spares.

Inactive warheads are maintained in a non-operational status at depots, and have their tritium bottles removed.

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Bulletin of the Atomic Scientists

U.S. nuclear forces, 2010

Two important recent events—the signing of New START and the release of the Obama administration's Nuclear Posture Review—will shape the configuration of the U.S. nuclear arsenal for years to come.

BY ROBERT S. NORRIS & HANS M. KRISTENSEN

In an unprecedented event, the Pentagon disclosed on May 3, 2010, that its total stockpile of nuclear weapons included 5,113 warheads, a size very close to what we have estimated on these pages. As of January, the United States maintained a nuclear arsenal of an estimated 2,468 operational warheads. The arsenal consists of roughly 1,968 strategic warheads deployed on 798 strategic delivery vehicles and 500 nonstrategic warheads. In addition, approximately 2,600 warheads are held in reserve. That adds up to a total stockpile of about 5,113 warheads. Several thousand retired warheads, probably 3,500-4,500, are awaiting dismantlement.

The number of weapons dismantled each year in 1994-2009 was also declassified, adding to the 1970-1997 list previously disclosed.[1] Secretary of State Hillary Clinton declared at the opening of the nuclear Non-Proliferation Treaty Review Conference in New York: "Beginning today, the United States will make public the number of nuclear weapons in our stockpile and the number of weapons we have dismantled since 1991." [2]

Two important events occurred in April that will have a significant impact on the future of U.S. nuclear forces. The first took place on April 6, when the Obama administration released its Nuclear Posture Review (NPR); the second came two days later, when U.S. President Barack Obama and Russian President Dmitry Medvedev signed New START, an arms control treaty that sets future limits on strategic weapons.[3] In terms of specific force levels, the NPR concludes that the United States can sustain stable nuclear deterrence with approximately 1,550 strategic warheads deployed on its triad of 700 land- and sea-based ballistic missiles and long-range bombers. These force levels are set in New START and must be realized within seven years of its ratification. The NPR also

THE U.S. NUCLEAR ARSENAL, 2010

TYPE/DESIGNATION	NO.	YEAR DEPLOYED	WARHEADS X YIELD (KILOTONS)	DEPLOYED
ICBMS				
LGM-30G Minuteman III				
Mk-12	~0	1970	1–3 W62 x 170 (MIRV)	~0[1]
Mk-12A	250	1979	1–3 W78 x 335 (MIRV)	250
Mk-21/SERV	200	2006[2]	1 W87 x 300	250
TOTAL	**450**			**500**
SLBMs[3]				
UGM-133A Trident II D5	288			
Mk-4		1992	4 W76 x 100 (MIRV)	568
Mk-4A		2008	4 W76-1 x 100 (MIRV)	200
Mk-5		1990	4 W88 x 455 (MIRV)	384
TOTAL	**288**			**1,152**
Bombers				
B-52H Stratofortress	93/44[4]	1961	ALCM/W80-1 x 5–150	216
B-2A Spirit	20/16	1994	B61-7/-11, B83-1	100
TOTAL	**113/60**			**316**[5]
Nonstrategic forces				
Tomahawk SLCM	325	1984	1 W80-0 x 5–150	(100)[6]
B61-3, -4 bombs	n/a	1979	0.3–170	400[7]
TOTAL	**>325**			**500**
GRAND TOTAL				**~2,468**[8]

1. The air force missed the October 1, 2009, deadline for the retirement of the W62 warhead, but we estimate the warhead has probably been removed from operational missiles.

2. The W87 was first deployed on the MX/Peacekeeper in 1986.

3. Two additional subs with 48 missile tubes are normally in overhaul and not available for deployment. Their 48 missiles with 288 warheads are considered part of the responsive force of reserve warheads. Delivery of the W76-1/Mk4A First Production Unit occurred in late October 2008, and the warhead formally entered the stockpile in early 2009.

4. The first figure is the aircraft inventory, including those used for training, testing, and backup; the second is the primary mission aircraft inventory, the number of operational aircraft assigned for nuclear and/or conventional missions.

5. The pool of bombs and cruise missiles allows for multiple loading possibilities depending on the mission. We estimate that the force level of 528 ALCMs of all categories by 2012 has already been achieved, of which 216 are operationally deployed on bases, and that gravity bombs are only operationally deployed with the B-2.

6. The TLAM/N is in the process of being retired.

7. Approximately 200 B61 bombs are deployed at six bases in five European NATO countries.

8. The U.S. government does not count spares as operational warheads. We have included them in the reserve, which we estimate contains approximately 2,600 warheads. Several thousand other retired warheads are awaiting dismantlement.

ALCM: air-launched cruise missile

ICBM: intercontinental ballistic missile

MIRV: multiple independently targetable reentry vehicle

SERV: security enhanced reentry vehicle

SLCM: sea-launched cruise missile

SLBM: submarine-launched ballistic missile

TLAM/N: tomahawk land attack missile-nuclear determines that the U.S. reserve of non-deployed warheads can be "significantly reduced," but that "some" warheads will continue to be stored in case of technical problems or international developments.[4]

Like previous arms control agreements, New START does not require the destruction of Russian and U.S. nuclear warheads, but it does limit how many can be deployed on ballistic missiles and bombers. In terms of verification, the treaty will count actual deployed warheads on ballistic missiles, but unlike the original START, it will attribute only one warhead to each nuclear-capable bomber. As a result, both Russia and the United States will be able to deploy all but a few dozen of the 1,550 warheads on ballistic missiles.[5] At the current rate of reductions, the U.S. could reach the New START limit as soon as this year.[6]

New declaratory nuclear policy. There are many differences between Obama's 2010 NPR and George W. Bush's 2001 NPR. Foremost among them is the country's declaratory nuclear policy. The Obama posture review states: "The fundamental role of U.S. nuclear weapons, which will continue as long as nuclear weapons exist, is to deter nuclear attack on the United States, our allies, and partners." [7] The objective to deter "nuclear" attack represents a narrowing of the Bush administration's policy to deter any attack involving "weapons of mass destruction," a designation that includes biological and chemical weapons.[8] Defense Secretary Robert Gates explained that "the term 'fundamental purpose' basically made clear—and other language makes clear—this is obviously a weapon of last resort." [9] The change was accordingly accompanied by a revamped negative security assurance: "The United States will not use or threaten to use nuclear weapons against non-nuclear weapon states that are party to the [Nuclear Non-Proliferation Treaty] and in compliance with their nuclear nonproliferation obligations." [10]

There is some uncertainty about whether this change in declaratory policy will actually affect the role of U.S. nuclear weapons. On *Face the Nation*, Gates explained, "The new part of this is that we would not use nuclear weapons against a non-nuclear state that attacked us with chemical and biological weapons." [11] Yet the 2010 NPR also states that among the countries not covered by the negative security assurance, "there remains a narrow range of contingencies in which U.S. nuclear weapons may still play a role in deterring a conventional or [chemical and biological weapons] attack against the United States or its allies and partners." Thus, the posture review concludes that Washington is "not prepared at the present time to adopt a universal policy that the 'sole purpose' of U.S. nuclear weapons is to deter nuclear attack on the United States and our allies and partners." [12]

In other words, if a country *is* in compliance with the Nuclear Non-Proliferation Treaty (NPT) and attacks the United States or its allies with chemical and biological weapons, then it will not be subject to nuclear retaliation. But if that country is *not* in compliance with the NPT (or if it possesses nuclear weapons) and it uses chemical, biological, or even conventional weapons against Washington or its allies and partners, then the United States might retaliate with nuclear weapons.

The 2010 NPR states that Washington "will not develop new nuclear warheads," although it leaves "new" undefined.

Either way, the role of U.S. nuclear weapons will probably remain the same. The U.S. strategic nuclear war plan includes six adversaries: Russia, China, North Korea, Iran, Syria, and a 9/11-type WMD attack by a non-state actor in cooperation with a nuclear state.[13] Russia and China are not affected by the change; North Korea and non-state actors are not NPT members; and Iran and Syria are not in full NPT compliance due to insufficient cooperation with the International Atomic Energy Agency (IAEA). (The determination of compliance is made by the United States, not the IAEA.)

Nuclear warhead production. The 2010 NPR states that Washington "will not develop new nuclear warheads," although it leaves "new" undefined. Washington might produce so-called life extension program warheads, but the posture review says life extension programs "will use only nuclear components based on previously tested designs and will not support new military missions or provide for new military capabilities." Under the Obama administration's plan, "the full range of [life extension program] approaches will be considered: refurbishment of existing warheads, reuse of nuclear components from different warheads, and replacement of nuclear components."

Mindful of the international repercussions of producing replacement warheads, the posture review promises, "Any decision to proceed to engineering development for warhead [life extension programs] . . . will give strong preference to options for refurbishment or reuse. Replacement of nuclear components would be undertaken only if critical Stockpile Management Program goals could not otherwise be met, and if specifically authorized by the president and approved by Congress." While this policy suggests that the Obama administration is unlikely to produce replacement warheads, it is broad enough to permit production of Reliable Replacement Warheads in the future.

For now, the NPR recommends three warhead production projects: (1) fully fund the W76-1 warhead for completion in fiscal 2017;

(2) produce the B61-12 starting in fiscal 2017; and (3) initiate a study on a W78 life extension program in fiscal 2010. To produce replacement plutonium cores ("pits") for nuclear weapons, the posture review not only funds the Chemistry and Metallurgy Research Replacement Project and Nuclear Facility at Los Alamos National Laboratory, but also allows for increased funding if necessary. At the moment, the facility is budgeted at $1.86 billion through fiscal 2015.[14] In 2008, the Bush administration proposed that the facility be able to produce 20 plutonium pits per year, with an emergency capacity of 80 pits per year by 2022. However, a 2009 study by the esteemed JASON panel of independent experts refuted claims that replacement warheads are needed because of existing warhead unreliability.[15] Nevertheless, a vigorous debate is expected this year over what it means to modernize U.S. forces and the related issue of whether life extension programs can, or should, add new military capabilities to existing warheads.

A vigorous debate is expected this year over what it means to modernize U.S. forces and the related issue of whether life extension programs can, or should, add new military capabilities to existing warheads.

Nuclear war planning and organization. The posture review's impact on the strategic U.S. nuclear war plan will become apparent later this year after Obama issues his first guidance to the military on how it should plan for the potential use of nuclear weapons. The current plan, known as Operations Plan (OPLAN) 8010-08 Strategic Deterrence and Global Strike, was put into effect in February 2008 and updated in February 2009.

It contains a "family" of strike plans against six adversaries (mentioned above) but focuses mainly on Russia and China, the potential adversaries with the largest arsenals. The strike plans consist of Selective Attack Options, Basic Attack Options, Emergency Response Options, and Directed/Adaptive Planning Capability Options designed to cover many contingencies and objectives. The strategic war plan no longer contains Major Attack Options, a hallmark of the Cold War-era Single Integrated Operational Plan.[16]

To practice OPLAN 8010-08, U.S. Strategic Command conducted the Global Thunder 09 nuclear exercise last September, testing the readiness of U.S. ballistic missiles and long-range bombers. Shortly afterward, Russia requested an "open display" of B-2 bombers at Whiteman Air Force Base (AFB) in Missouri and an intercontinental ballistic missile (ICBM) reentry vehicle on-site inspection at Warren AFB in Wyoming in accordance with START. These were the last Russian inspections in the United States under the treaty, which expired on December 5, 2009.

In an effort to increase the readiness and proficiency of its nuclear mission, the air force recently reorganized its nuclear command structure. In particular, Air Force Global Strike Command, based at Barksdale AFB in Louisiana, took control of the ICBM force on December 1, 2009, and the long-range bomber force on February 1, 2010, consolidating all strategic air force wings under one command. The 798th Munitions Maintenance Group was set up at Minot AFB in North Dakota in August 2009 to lead maintenance, handling, and surveillance of the ICBM arsenal. Meanwhile, the 498th Munitions Maintenance Group was relocated from Kirtland AFB in New Mexico to Whiteman to oversee the bombers. It commands the 898th Munitions Squadron and the 708th Nuclear Sustainment Squadron at Kirtland AFB and is subordinate to the 498th Nuclear Systems Wing at Kirtland, which is responsible for sustaining nuclear bombs and cruise missiles. In addition, standardization and training of nuclear inspection teams have been changed to improve the quality of the 10-14 Nuclear Surety Inspections that are performed annually across the major commands.

It is unclear whether the ICBM force will be reduced under New START; there are several possibilities, including retiring 50–150 missiles. The decision will be contentious because it will affect budgets and jobs at air force bases in Wyoming, Montana, and North Dakota.

Land-based ballistic missiles. The U.S. ICBM force has undergone significant changes since the Moscow Treaty was signed in 2002; it will continue to change under New START. Approximately 500 warheads are now deployed on 450 ICBMs—a reduction of 50 warheads from 2009 levels, due to the retirement of the 170-kiloton W62 warhead. (All W62 warheads have probably been removed from operational missiles, although the Pentagon missed its September 2009 deadline for retiring the weapon completely.) The modern 300-kiloton Mk 21/W87 Safety Enhanced Reentry Vehicle is replacing the W62; the W87's increased yield and accuracy broadens the range of targets of the Minuteman ICBM force.

After the START II requirement to reduce ICBMs' nuclear payload to a single warhead was abandoned, the Bush administration decided to retain some missiles with multiple independently targetable reentry vehicles (MIRVs). In a reversal, the Obama NPR has determined that the ICBMs will be "de-MIRVed" after all, although the capability to re-MIRV the missiles will be retained. It is unclear whether the ICBM force will be reduced under New START; there are several possibilities, including retiring 50–150 missiles. The decision will be contentious because it will affect budgets and jobs at air force bases in Wyoming, Montana, and North Dakota.

The multi-year, $7 billion upgrade of the Minuteman III ICBM is nearly complete, and the service life of the Minuteman III has been extended to 2030, delaying plans to deploy a replacement ICBM in 2018. The NPR decided to begin studies in 2011-2012 for a new ICBM to replace the Minuteman III sometime between 2030 and 2040. The study will examine "a range of possible deployment options" that "support continued reductions in U.S. nuclear weapons while promoting stable deterrence."[17]

The 341st Missile Wing Plans and Programs Office stated, "An Empty Quiver has generally been seen as an impossibility, but due to an ever-changing and diverse threat environment . . . the [United States] no longer has the luxury of assuming what is and what is not possible."

There were two Minuteman III flight-tests in 2009, compared to four in 2008. A missile taken from Minot AFB was test-launched from Vandenberg AFB in California on June 29; the three unarmed W78/Mk-12A reentry vehicles flew approximately 6,740 kilometers (4,190 miles) to near Kwajalein Atoll in the Marshall Islands. On August 23, another Minuteman III, probably from Malmstrom AFB, was test-launched with a single reentry vehicle over the same range. Additional simulated launches occurred at the ICBM bases; one exercise took place at Minot AFB in May, and another took place one month later.

The ICBM wings also conducted several nuclear exercises during 2009. In June at Warren AFB, 1,300 personnel from 11 federal agencies conducted Nuclear Weapons Accident/Incident Exercise 2009, a simulated terrorist attack against the base. And between November 30 and December 9 at Warren AFB, the 20th Air Force carried out a Combat Capability Evaluation, which was followed by a no-notice Limited Nuclear Surety Inspection conducted by Air Force Global Strike Command.

The 15th Munitions Squadron stood up at Warren AFB in August 2009 to assume responsibility for the weapons storage area that houses the base's nuclear weapons. (It replaced the 90th Missile Maintenance Squadron.) That same month, the 16th Munitions Squadron was activated at Malmstrom AFB to operate the weapons storage area there.

The 341st Missile Wing at Malmstrom received a Limited Nuclear Surety Inspection in early February 2009, which was a re-inspection prompted by a failed Nuclear Surety Inspection in October 2008. Two months later, the wing was the focus of a simulated "Empty Quiver" incident, during which 120-150 personnel practiced how to respond to, and recover, a lost, stolen, or seized nuclear warhead. The 341st Missile Wing Plans and Programs Office stated, "An Empty Quiver has generally been seen as an impossibility, but due to an ever-changing and diverse threat environment . . . the [United States] no longer has the luxury of assuming what is and what is not possible."[18]

The 92nd Missile Wing at Minot AFB underwent a no-notice Limited Nuclear Surety Inspection from the Air Force Global Strike Command in the first week of December 2009.

Ballistic missile submarines. On March 27, 2009, the nuclear-powered ballistic missile submarine (SSBN) *Alaska* arrived at Kings Bay Naval Submarine Base in Georgia after completing a 26-month refueling overhaul at the Norfolk Naval Shipyard in Virginia. The SSBN was previously based at Bangor Naval Submarine Base in Washington. The transfer completes the realignment of SSBNs between the Pacific and Atlantic coasts and increases the number of SSBNs based at Kings Bay from five to six. The remaining eight SSBNs are based at Kitsap Naval Submarine Base near Bangor. The 2010 NPR recommends retaining a fleet of 14 SSBNs for the time being, but two boats could be retired toward the end of the decade. The 12-boat force level matches the navy's long-range shipbuilding plan. The posture review also supports development of a follow-on to the Ohio-class SSBN, which will begin retiring in 2027. Each new submarine, tentatively known as SSBN(X), will probably carry 16 submarine-launched ballistic missiles (SLBMs).

The 12 operational SSBNs carry a total of 288 Trident II D5 SLBMs. (Two additional SSBNs undergo overhaul at any given time; their 48 missiles and associated warheads are not counted by the Moscow Treaty or New START.) We estimate that each missile carries an average of four warheads for a total of 1,152 warheads on the 12 deployed SSBNs. Surprisingly, the 2010 NPR declares that even if Washington reduces the SSBN force to 12 boats, "this decision will not affect the number of deployed nuclear warheads on SSBNs."[19] Apparently, the Trident force has been the predominant U.S. nuclear strike platform for some time and seems to increase in importance under New START. Together with bombers, the SSBNs will be the main upload platform for reserve warheads.

The SSBN force conducted 31 strategic deterrent patrols during 2009, the same number as in 2008. With eight SSBNs based in the Pacific Ocean versus six in the Atlantic Ocean and a patrol rate comparable to that of the Cold War, more than two-thirds of U.S. SSBN patrols now take place in the Pacific, compared to only one-seventh during the 1980s. This change reflects a shift in strategic focus from the Soviet Union/Russia to China and other potential adversaries in the Pacific region.

Procurement of the D5LE, a modified Trident II D5 SLBM, began in 2008 and doubled from 12 to 24 missiles in 2009. A total of 108 missiles will be purchased through 2012, at a cost of more than $4 billion. The first D5LE will be deployed this year. It will arm Ohio-class SSBNs for the rest of their service lives, which have been extended from 30 to 44 years.

In terms of age, the oldest SSBN is scheduled to retire in 2027, followed by the next boat in 2030, reducing the SSBN force to 12. To offset subsequent retirements, the navy plans to begin building the first SSBN(X) boat in 2019, the second boat in 2022, and another boat every year from 2024 until 2033.[20] The first SSBN(X) is scheduled to become operational in 2029. It will likely carry fewer missiles than the current Ohio-class SSBN—probably 16—to permit more boats under future arms control agreements and more operational flexibility. The new SSBN program is projected to cost more than $80 billion.

Deployment of the W76-1/Mk-4A warhead, a modernized version of the existing W76/Mk-4, is under way. The warhead is equipped with a new fuse that allows more flexibility in setting the height of burst, which, according to the Energy Department, would "enable W76 to take advantage of [the] higher accuracy of [the] D5 missile" and bring more targets, including hard targets, within range.[21] The first W76-1/Mk-4A was delivered in late October 2008 and entered the stockpile in February 2009. The Bush administration decided in 2005 to upgrade 63 percent of the 2001 inventory of W76s—corresponding to roughly 2,000 warheads—by fiscal 2021. The 2010 posture review speeds up the completion date of this program to fiscal 2017.[22]

Similar to the air force command reorganization, the navy recently split its Submarine Group Trident in two; one half now oversees Submarine Group 10 at Kings Bay, and the other oversees Submarine Group 9 at Kitsap. Submarine Group 10 will be further subdivided with two different commodores, one for the SSBNs of Submarine Squadron 20, and the other for the cruise-missile submarines of Submarine Squadron 16.

Last year, U.S. SSBNs flight-tested four Trident II D5 missiles. The *Alabama* launched one D5 in the Pacific on February 3. The *West Virginia* launched one missile in the Atlantic on September 3 and another on the following day. Finally, the *Alaska* launched a D5 in the Atlantic on December 19, marking the 130th consecutive successful D5 flight test since 1989.[23] (A media report from early 2010 that a U.S. SSBN test-launched an SLBM during an exercise in the Middle East is untrue.)

Strategic bombers. The air force possesses 20 B-2s and 93 B-52Hs, of which 18 and 76, respectively, are nuclear-capable. Of these, only 16 B-2s and 44 B-52s are thought to be fully nuclear certified at any given moment. The 2010 NPR determines that some of the nuclear-capable B-52s will be converted to a conventional-only role.

For the past several years, we have estimated that approximately 500 of the 2,140 deployed strategic warheads were deployed at Barksdale, Minot, and Whiteman AFBs. But in connection with the signing of New START, we learned that the air force has removed more warheads from the bases. Consequently, we estimate that only 316 bomber weapons are left across the three bases. The bomber weapons include B61-7, B61-11 (for B-2s only), and B83-1 gravity bombs and the air-launched-cruise-missile-delivered W80-1 (for B-52Hs only). Since New START does not count actual bomber weapons (only aircraft), the pressure to reduce weapons on the bomber bases is gone.

As for force enhancements, in December 2009, the air force authorized full-scale production of new advanced radars for its B-2s. The $1.2 billion program will provide the bombers with advanced electronically scanned array antennas. The first B-2 fitted with the new radar was delivered in March 2009, and the upgrade will be complete by 2011. The NPR announces that the Defense Department "will invest more than $1 billion over the next five years to support upgrades to the B-2 stealth bomber. These enhancements will help sustain survivability and improve mission effectiveness."[24]

In terms of inspections and tactical exercises, the 2nd Bomb Wing at Barksdale AFB received Nuclear Surety Staff Assistance Visits last summer in preparation for a Nuclear Surety Inspection. A no-notice Nuclear Surety Inspection was held two months later and another in January. In February 2009, B-52Hs from the 2nd Bomb Wing conducted a Global Power training mission, during which they flew across the Atlantic Ocean, traveled over the Mediterranean Sea, and landed at Diego Garcia in the Indian Ocean. Afterward, they continued east, stopping at Andersen AFB in Guam, before heading back to Barksdale AFB. "This sends a clear message that we can hold any target at risk throughout the globe," according to a Bomb Wing statement. "Our demonstration of our capability is a critical part of the deterrence equation."[25] The Global Power mission was followed by a four-month extended forward deployment of B-52Hs from the 2nd Bomb Wing to Andersen.

The 5th Bomb Wing at Minot AFB conducted a Bomber Strategic Aircraft Regeneration Team exercise on January 28, 2009, that simulated setting up an alternative deterrent base at a forward location. Similarly, a nuclear operational readiness exercise known as Prairie Vigilance 09-7 was conducted over a period of 10 days starting in late April 2009. It involved 12 B-52Hs from both Minot and Barksdale AFBs and more than 3,500 personnel and was intended to demonstrate the U.S. ability to employ nuclear weapons. The wing received a no-notice Nuclear Surety Inspection about a month later. In September, it absorbed the 69th Bomb Squadron, which enables B-52H squadrons from Minot and Barksdale AFBs to focus one squadron on the nuclear mission for six-month intervals. Consequently, 10 B-52Hs will gradually transfer from Barksdale to Minot, eventually increasing the total number of combat-ready B-52Hs at Minot from 12 to 22. In preparation for the transfer, the 69th Bomb Squadron received its Initial Nuclear Surety Inspection in January 2010.

The latest NPR does not make a public decision on the future of the nuclear deployments in Europe. Instead, it leaves it to NATO's Strategic Review process to determine the future role of nuclear weapons in the alliance.

The B-2s of the 509th Bomb Wing at Whiteman conducted numerous nuclear exercises and inspections in 2009, including two no-notice Nuclear Surety Inspections. Additionally, a Nuclear Operational Readiness Exercise was held there on August 10; a week later, the 72nd Test and Evaluation Squadron for Air Combat Command conducted a nuclear weapons system evaluation program inspection. A second Nuclear Operational Readiness Exercise called Spirit Force 09-5 was held on September 29, followed by a Nuclear Operational Readiness Inspection a few weeks later. Four B-2s from the wing's 13th Bomb Squadron deployed for a four-month extended deployment at Andersen AFB. They were accompanied by 14 F-22s, marking the first time the two stealth aircraft had been deployed simultaneously to Guam. During the forward deployment, the B-2s and F-22s carried out a 24-hour, 16,000-kilometer (9,940-mile) training exercise to Alaska and back to showcase the global reach of the U.S. bomber force. After dropping 20 joint direct attack munitions on the Alaska Range Complex, the B-2s "then took part in the large-force portion of the exercise with F-22s providing escort to the B-2s into a highly defended area by Red Air threats and by surface-to-air missiles," according to an air force press release. "The overall point of the exercise was to coordinate the B-2s and the F-22s through a low observable integration mission."[26]

Nonstrategic nuclear weapons. The United States retains approximately 500 active nonstrategic nuclear warheads. These consist of approximately 400 B61 gravity bombs and 100 W80-0 warheads for sea-launched, land-attack Tomahawk (TLAM/N) cruise missiles. Another 700–800 nonstrategic warheads, including roughly 190 W80-0 warheads, are in inactive storage. Neither the Moscow Treaty nor New START places limits on Russian and U.S. inventories of nonstrategic nuclear weapons.

About 200 B61 bombs are deployed in Europe at six airbases in five NATO countries (Belgium, Germany, Italy, the Netherlands, and Turkey).[27] The aircraft that are assigned nuclear strike missions with U.S. nuclear weapons include Belgian and Dutch F-16s and German and Italian Tornadoes. Although they no longer are thought to have a nuclear strike mission, Turkish and Greek aircraft occasionally participate in NATO's Steadfast Noon nuclear exercises, probably as air defense aircraft.

The latest NPR does not make a public decision on the future of the nuclear deployments in Europe. Instead, it leaves it to NATO's Strategic Review process to determine the future role of nuclear weapons in the alliance. The posture review states that the F-35 Joint Strike Fighter will be equipped with a B61 nuclear capability starting in 2017 to replace F-15s and F-16s in the nuclear strike role. Even if the weapons are withdrawn from Europe, the U.S. plans a fleet of nuclear F-35s in the United States to "retain the capability to forward-deploy non-strategic nuclear weapons in support of its Alliance commitments."

In a significant development, the 2010 NPR recommends that the nuclear version of the TLAM be retired. Designed for deployment on selective attack submarines, the TLAM/N is now stored at the SSBN bases in Washington and Georgia.

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Stockpile management. The total U.S. stockpile of roughly 5,100 warheads is organized in two overall categories: active and inactive warheads. The deployed category includes 2,468 intact warheads (with all the components) deployed on operational delivery systems. The approximately 2,600 non-deployed warheads are either active in the "responsive force" that can be deployed on operational delivery systems in a relatively short amount of time or inactive and in long-term storage with their limited-life components (i.e., tritium) removed. Several thousand retired warheads, probably 3,500-4,500, are awaiting dismantlement.

The nearly 14,000 pits (plutonium cores) that the United States stores at Pantex make up most of the 38 tons of plutonium reserved for nuclear weapons. The stockpiled warheads contain roughly 15 tons of plutonium, or an average of three kilograms per warhead. More than 5,000 thermonuclear secondaries, or canned assemblies, are kept at the Oak Ridge Y-12 Plant in Tennessee. ■

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NOTES

1. U.S. Department of Defense, *Increasing Transparency in the U.S. Nuclear Weapons Stockpile*, Fact Sheet, May 3, 2010. Available at http://www.defense.gov/npr/docs/10-05-03_Fact_Sheet_US_Nuclear_Transparency__FINAL_w_Date.pdf; U.S. Department of Defense, Background Briefing on Nuclear Stockpile, May 3, 2010. Available at http://www.defense.gov/advisories/advisory.aspx?advisoryid=3211

2. U.S. Department of State, *Remarks at the Review Conference of the Nuclear Nonproliferation Treaty*, May 3, 2010. Available at http://www.state.gov/secretary/rm/2010/05/141424.htm

3. Officials New START documents are available at http://www.state.gov/t/vci/trty/126118.htm

4. The Nuclear Posture Review and other official documents relating to U.S. nuclear policy are available at http://www.defense.gov/npr/

5. The State Department website includes the text and protocol of New START, as well as many other fact sheets and documents. U.S. Department of State, "New Strategic Arms Reduction Treaty (New START)," Bureau of Verification, Compliance, and Implementation. Available at http://www.state.gov/t/vci/trty/126118.htm.

6. See: Hans M. Kristensen, "U.S. Moves Rapidly Toward New START Warhead Limit," FAS Strategic Security Blog, May 2, 2010, available at http://www.fas.org/blog/ssp/2010/05/downloading.php

7. U.S. Department of Defense, Office of the Secretary of Defense, *Nuclear Posture Review Report*, April 2010, p. vii. Available at http://www.defense.gov/npr/docs/2010%20Nuclear%20Posture%20Review%20Report.pdf.

8. The previous declaratory policy, stated most recently in February 2008 by Stephen Hadley, then national security advisor: "The United States has made clear for many years that it reserves the right to respond with overwhelming force to the use of *weapons of mass destruction* against the United States, our people, our forces, and our *friends* and allies. *Additionally*, the United States will hold any state, *terrorist group, or other non-state actor* fully accountable for supporting or enabling terrorist efforts to obtain or use weapons of mass destruction, whether by facilitating, financing, or providing expertise or safe haven for such efforts." Emphasis added. White House, "Remarks by the National Security Advisor, Stephen Hadley, to the Center for International Security and Cooperation," February 8, 2008, p. 5.

9. U.S. Department of Defense, "DOD News Briefing with Secretary Gates, Navy Adm. Mullen, Secretary Clinton, and Secretary Chu from the Pentagon," April 6, 2010. Available at http://www.defense.gov/Transcripts/Transcript.aspx?TranscriptID=4599.

10. U.S. Department of Defense, Office of the Secretary of Defense, *Nuclear Posture Review Report*, April 2010, p. viii. Available at http://www.defense.gov/npr/docs/2010%20Nuclear%20Posture%20Review%20Report.pdf. The previous formulation, first adopted in 1978, and restated in 2002, said: "[The United States] will not use nuclear weapons against non-nuclear weapon states parties to the [Nuclear Non-Proliferation Treaty], except in the case of an invasion or any other attack on the United States, its territories, its armed forces or other troops, its allies, or on a state toward which it has a security commitment, carried out or sustained by such a non-nuclear weapon state in association or alliance with a nuclear weapon state." See Philipp C. Bleek, "Bush Administration Reaffirms Negative Security Assurances," *Arms Control Today*, March 2002. Available at http://www.armscontrol.org/print/1010.

11. U.S. Department of State, "Interview with Bob Schieffer of CBS's 'Face the Nation,' Hillary Rodham Clinton, Secretary of State, Robert Gates, Secre-

tary of Defense," April 9, 2010. Available at http://www.state.gov/secretary/rm/2010/04/139974.htm.

12. U.S. Department of Defense, Office of the Secretary of Defense, *Nuclear Posture Review Report*, April 2010, p. 16. The Nuclear Posture Review cautions that despite the pledge not to use nuclear weapons against non-nuclear weapon states that are in compliance with the Nuclear Non-Proliferation Treaty, because of the catastrophic potential of biological weapons and the rapid pace of biotech development, "the United States reserves the right to make any adjustment in the assurance that may be warranted by the evolution and proliferation of the biological weapons threat and U.S. capacities to counter that threat."

13. Hans M. Kristensen, "Obama and the Nuclear War Plan," Federation of American Scientists (FAS) Strategic Security Blog, February 2010, p. 3. Available at http://www.fas.org/programs/ssp/nukes/publications1/WarPlanIssueBrief2010.pdf.

14. U.S. National Nuclear Security Administration (NNSA), "FY2011 Congressional Budget Request," February 2010, pp. 173–74. See also NNSA, "Record of Decision for the Complex Transformation Supplemental Programmatic Environmental Impact Statement: Operations Involving Plutonium, Uranium, and the Assembly and Disassembly of Nuclear Weapons," *Federal Register*, vol. 73, no. 245, December 19, 2008, pp. 77647–56. Available at http://edocket.access.gpo.gov/2008/pdf/E8-30194.pdf.

15. JASON Program Office, "Life Extension Program, Executive Summary," MITRE Corporation, September 9, 2009. Available at http://www.fas.org/programs/ssp/nukes/nuclearweapons/jason2009.pdf.

16. Hans M. Kristensen, *Obama and the Nuclear War Plan*, FAS Issue Paper, February 2010, available at http://www.fas.org/blog/ssp/2010/02/warplan.php

17. Office of the Secretary of Defense, *Nuclear Posture Review Report*, April 2010, p. 23. Available at http://www.defense.gov/npr/docs/2010%20Nuclear%20Posture%20Review%20Report.pdf.

18. U.S Air Force, 341st Missile Wing Plans and Program Office, "Interagency Nuclear Recovery Exercise to Take Place," April 15, 2009.

19. U.S. Department of Defense, Office of the Secretary of Defense, Nuclear Posture Review Report, April 2010, p. 22.

20. Ronald O'Rourke, "Navy Force Structure and Shipbuilding Plans: Background and Issues for Congress," Congressional Research Service Report for Congress, RL32665, December 22, 2009, pp. 7, 11.

21. U.S. Department of Energy, Office of Defense Programs, *Stockpile Stewardship and Management Plan: First Annual Update* (Energy Department: Washington, D.C., October 1997), pp. 1–14. (Partially declassified and released under the Freedom of Information Act.)

22. U.S. Department of Defense, Office of the Secretary of Defense, *Nuclear Posture Review Report*, April 2010, p. 16. For the Bush administration's 2005 decision, see Hans M. Kristensen, "Administration Increases Submarine Nuclear Warhead Production Plan," FAS Strategic Security Blog, August 30, 2007. Available at http://www.fas.org/blog/ssp/2007/08/us_tripples_submarine_warhead.php. For the statement about a ramped-up production rate, see Brig. Gen. Garrett Harencak, U.S. Air Force, Principle Assistant Deputy Administrator for Military Application, "Statement Before the Subcommittee on Energy and Water Development of the House Appropriations Committee, Hearing on the Department of Energy Weapons Activities and Naval Reactors, 2011 Budget," March 4, 2010, Federal News Service transcript, p. 11.

23. In addition to the U.S. Navy flight tests, the Royal Navy ballistic missile submarine *Victorious* launched a Trident II D5 in the Atlantic Ocean on May 26, 2009, as part of an exercise following a refueling overhaul.

24. U.S. Department of Defense, Office of the Secretary of Defense, *Nuclear Posture Review Report*, April 2010, p. 24.

25. U.S. Air Force, 2nd Bomb Wing Public Affairs, "2nd Bomb Wing Conducts Global Power Mission," February 5, 2009.

26. U.S. Air Force, 36th Wing Public Affairs, "B-2 Aircrafts Complete Polar Lightning Exercise," May 15, 2009.

27. On the history and status of U.S. nuclear weapons in Europe, see Hans M. Kristensen, "U.S. Nuclear Weapons in Europe: A Review of Post-Cold War Policy, Force Levels, and War Planning," Natural Resources Defense Council, February 2005. Available at http://www.nukestrat.com/pubs/EuroBombs.pdf. See also Hans M. Kristensen, "Kleine Brogel Nukes: Not There, Over Here!" FAS Strategic Security Blog, February 12, 2010. Available at http://www.fas.org/blog/ssp/2010/02/kleinebrogel2.php.

Robert S. Norris & Hans M. Kristensen, "U.S. nuclear forces, 2010," Bulletin of the Atomic Scientists, May/June 2010, vol. 66, no. 3, pp. 57–70.

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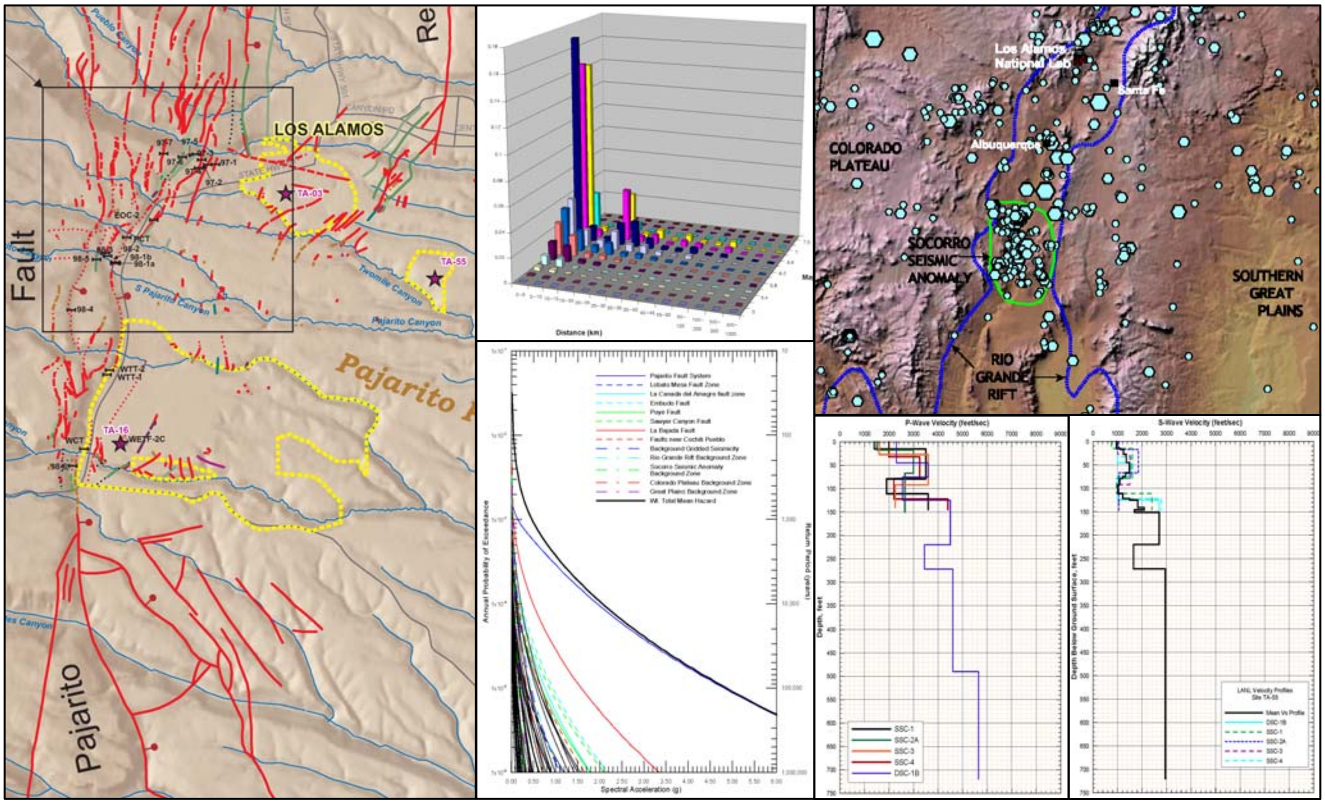
F I N A L   R E P O R T

Mello Aff #1, par 16, ref 1: http://www.lasg.org/LANL_PSHA_2007.pdf

UPDATE OF THE PROBABILISTIC SEISMIC HAZARD ANALYSIS AND DEVELOPMENT OF SEISMIC DESIGN GROUND MOTIONS AT THE LOS ALAMOS NATIONAL LABORATORY



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At the request of the Los Alamos National Laboratory (LANL), URS Corporation and Pacific Engineering & Analysis (PE&A), with support from the Earth and Environmental Sciences Division at LANL, have updated the 1995 probabilistic seismic hazard analysis (PSHA) of LANL (Wong *et al.*, 1995), and developed Design/Evaluation Basis Earthquake (DBE) ground motion parameters. Both Uniform Hazard Response Spectra (UHRS) and Design Response Spectra (DRS) have been calculated per ASCE/SEI 43-05 for the site of the Chemistry and Metallurgical Research Replacement (CMRR) building and for Technical Areas TA-3, TA-16, and TA-55. Site-wide and reference rock-outcrop (dacite) ground motions have also been developed and are recommended for use in the design of facilities in other Technical Areas. DRS were computed for Seismic Design Categories (SDC)-3 (2,500-year return period), -4 (2,500 years), and -5 (10,000 years).

The PSHA was conducted following the guidelines of the Senior Seismic Hazard Analysis Committee for a Level 2 PSHA. Principal inputs required for the development of the DBE ground motions include a seismic source model, ground motion attenuation relationships, and velocity and nonlinear dynamic properties of the lower Quaternary (1.2 to 1.6 Ma) Bandelier Tuff beneath each site.

Since 1995, the only new geotechnical, geologic, and geophysical data available to characterize the dynamic properties of the subsurface geology beneath LANL, particularly the Bandelier Tuff, are the results of investigations performed at the CMRR site. Downhole-velocity, OYO-suspension velocity, and seismic crosshole surveys were performed in boreholes drilled in 2005 at that site. The boreholes include four shallow holes at the corners of the proposed CMRR building footprint (SSC-1 to SSC-4), one deep hole in the center of the footprint (DSC-1B), and a deep hole outside and to the east of the footprint (DSC-2A). Dynamic laboratory testing was also performed by the University of Texas at Austin (UTA) on 22 samples collected in the CMRR boreholes. The dynamic properties that were evaluated are the strain-dependent shear modulus (G) and material damping ratio (D) of the samples. Based principally on the new CMRR data and data collected in 1995, base-case profiles of low-strain shear-wave velocity (V_S) and compressional-wave velocity (V_P) were developed for the CMRR, TA-3, TA-16, and TA-55 sites. Of particular significance to the site response analysis was the existence of the geologic unit Qbt3L, a low-velocity zone within the Bandelier Tuff. Unit-specific shear-modulus reduction and damping curves were developed on the basis of the dynamic laboratory testing results, including the 1995 testing. One set of curves for each unit was corrected for sample disturbance by adjusting reference strains by the ratio of laboratory-to-field V_S measurements.

The 50-km-long Pajarito fault system (PFS) extends along the western margin of LANL and is the dominant contributor to the seismic hazard at the laboratory because of its close proximity and rate of activity. The current (or new) characterization of the PFS is significantly revised from the 1995 study in order to incorporate a considerable amount of new mapping, displacement measurements, and paleoseismic data for the PFS. The PFS is a broad zone of faults that form an articulated monoclinal flexure, which consists of several distinct fault segments that have linked together. The PFS exhibits complex rupture patterns and shows evidence for at least two, probably three surface-faulting earthquakes since 11 ka. This recent temporal clustering of events is in contrast to evidence for the occurrence of only six to nine events since 110 ka although this longer record is likely incomplete. For the new analysis, both segmented and unsegmented rupture models were considered for the PFS, favoring the latter which is characterized by a 36-km-long, floating earthquake rupture source. Two types of multisegment ruptures for the PFS were also considered: simultaneous (a single large earthquake) and synchronous (two subevents). The preferred range of maximum earthquakes is from moment magnitude (**M**) 6.5 to 7.3. Recurrence rates are dependent on rupture model and both long-term slip rate and late Quaternary recurrence interval data were considered. For the preferred unsegmented rupture model, the weighted-mean slip rate was 0.21 mm/yr, and weighted mean recurrence intervals were 4,400 years (for the logic tree branch assuming temporal clustering) and 17,600 years (for the not-in-a-cluster branch). For the segmented rupture model, a moment-balancing approach was used similar to that used by the Working Group on California Earthquake Probabilities (2003) to partition the slip rate of a segment into earthquakes representing various rupture scenarios and to keep the fault in moment equilibrium. Thus, rates vary for each rupture scenario but overall were consistent with the long-term slip rates of the segmented rupture model.

In addition to the dominant PFS, 55 additional fault sources were included in the PSHA. Parameters that were characterized for each fault include: (1) rupture model including independent versus dependent, single plane versus zone, segmented versus unsegmented, and linked configurations; (2) probability of activity; (3) fault geometry including rupture length, rupture width, fault orientation, and sense of slip; (4) maximum magnitude (**M**); and (5) earthquake recurrence, including both recurrence models and rates (using recurrence intervals and/or fault slip rates). There are sparse data on rates of activity for many faults so the approach developed by McCalpin (1995) was applied to characterize fault slip rate distributions. McCalpin's analysis was updated, adding 15 slip rate observations from six additional faults.

In addition to active faults, three areal earthquake source zones were defined based on seismotectonic provinces in the LANL region: the Rio Grande rift, Southern Great Plains, and Colorado Plateau. Due to its high level of seismicity, the Socorro Seismic Anomaly was also modeled as an areal source zone and differentiated from the Rio Grande rift. Earthquake recurrence rates computed for each areal source zone are based on an updated (through 2005) historical seismicity catalog. In addition to the traditional approach of using areal source zones, Gaussian smoothing with a spatial window of 15 km was used to address the hazard from background seismicity and to incorporate a degree of stationarity. The two approaches, areal sources and Gaussian smoothing were weighted equally to compute the hazard from background seismicity in the PSHA.

A combination of both empirical and site-specific attenuation relationships were used in the PSHA. The empirical models were weighted as follows: Abrahamson and Silva (1997), modified for normal faulting, 0.45; Spudich *et al.* (1999), 0.35; Campbell and Bozorgnia (2003), 0.10; Sadigh *et al.* (1997), 0.05; and Boore *et al.* (1997), 0.05. The relationships were weighted based on their appropriateness for the extensional Rio Grande rift. Because the epistemic variability was deemed insufficient as provided by the five attenuation relationships, they were all scaled to obtain a total sigma (ln) of 0.4.

To compensate for the lack of region-specific attenuation relationships, the stochastic ground motion modeling approach was used, as it was in 1995, to develop site-specific relationships for LANL. The point-source version of the stochastic methodology was used to model earthquakes from **M** 4.5 to 8.5 in the distance range of 1 to 400 km. To accommodate finite-source effects at large magnitudes (**M** > 6.5), model simulations included an empirical magnitude-dependent short-period saturation as well as a magnitude-dependent far-field fall off. Relationships were developed for the CMRR, TA-3, TA-16, and TA-55 sites. A relationship for dacite was also developed. Aleatory variabilities in stress drop, magnitude-dependent point-source depths, the crustal attenuation parameters Q_o and η, and kappa were included in the computations of the attenuation relationships through parametric variations. Site-specific profiles (low-strain V_S, and V_P down to dacite) as well as modulus-reduction and hysteretic-damping curves were also randomly varied.

Variability (aleatory) in the regression of the simulated data is added to the modeling variability to produce 16th, 50th (median), and 84th percentile attenuation relationships. Thirty simulations were made for each magnitude and distance, and the results fitted with a functional form that accommodates magnitude-dependent saturation as well as far-field fall-off. Twelve attenuation relationships developed for the CMRR site were derived from three stress drops, two velocity models, and two sets of dynamic material properties. For the TA-3, TA-16, and TA-55 sites there were nine attenuation relationships derived from three stress drops, one velocity profile, and three sets of dynamic curves. There were six attenuation relationships for dacite derived from one profile, two sets of dynamic curves, and three stress drops.

In the 1995 study, attention was focused on potential topographic effects on ground motions due to the location of LANL facilities on mesas. In this study, a suite of topographic amplification factors was developed for LANL on the basis of (1) recent LANL modeling results, (2) other modeling results and observations in the literature, and (3) recommendations of Eurocode 8. The amplification factors are based on slope angles following Eurocode 8 as well as the French Seismic Code. To accommodate a fully probabilistic hazard analysis, both median estimates and standard deviations were developed, based on ranges of factors in modeling results and observations.

Probabilistic seismic hazard was calculated for the ground surface at CMRR, TA-3, TA-16, TA-55 and the top of dacite at TA-55. The hazard from the site-specific stochastic and empirical western U.S. soil attenuation relationships was calculated separately for each type of relationship. The modeling shows that the probabilistic hazard for peak horizontal ground acceleration (PGA) at all the above sites is controlled primarily by the PFS at all return periods. The PFS similarly controls the hazard at LANL for longer-period ground motions, such as 1.0 sec spectral acceleration (SA). Background seismicity in the Rio Grande rift, which contributed to the hazard at LANL in the 1995 study, is not a significant contributor in this new analysis, probably due to the increased activity rate of the PFS in the Holocene (clustering).

In calculating the probabilistic ground motions at LANL, the surface motions must be hazard consistent; that is, the annual exceedance probability of the soil UHRS should be the same as the rock UHRS. In NUREG/CR-6728, several site response approaches are recommended for use to produce soil motions consistent with the rock outcrop hazard. These approaches also incorporate site-specific aleatory variabilities of soil properties into the soil motions. To compute the site-specific ground-shaking hazard at LANL, we used two different approaches: (1) empirical attenuation relationships for the western U.S. (WUS) generic deep firm soil and (2) site-specific attenuation relationships. In the case of the latter, the site response is contained in the stochastic attenuation relationships (Approach 4). For the empirical attenuation relationships, the computed generic soil hazard curves from the PSHA were adjusted for the site-specific site conditions at each of the LANL sites using computed amplification factors (Approach 3).

The point-source version of the stochastic ground motion model was used to generate the amplification factors (the ratios of the response spectra at the top of the site profiles to the WUS soil). They are a function of the reference (WUS deep firm soil) peak acceleration, spectral frequency, and nonlinear soil response. Amplification factors were computed for CMRR (4 sets), TA-3 (3 sets), TA-16 (3 sets), and TA-55 (3 sets), based on the velocity profiles and properties, but only one set was computed for the top of dacite. The point-source stochastic model was also used to compute site-specific vertical-to-horizontal (V/H) ratios. To accommodate model epistemic variability following the approach used for the horizontal hazard analyses, empirical deep firm soil V/H ratios were also used with equal weights between the stochastic and empirical models.

The hazard curves derived from the empirical attenuation relationships and the amplification factors were used to calculate site-specific hazard curves using Approach 3. These hazard curves and the hazard curves based on site-specific stochastic attenuation relationships (Approach 4) were then weighted equally and the topographic amplification factors and V/H ratios were applied. In seismic hazard analyses, epistemic uncertainty (due to lack of knowledge) of parameters and models is typically represented by a set of weighted hazard curves. Using these sets of curves as discrete probability distributions, they can be sorted by the frequency of exceedance at each ground-motion level and summed into a cumulative probability mass function. The weighted-mean hazard curve is the weighted average of the exceedance frequency values.

Based on the final site-specific hazard curves, mean horizontal UHRS were computed for CMRR, TA-3, TA-16, and TA-55. The TA-55 UHRS is based on an envelope of the hazard curves of CMRR and the hazard curve developed on basis of the 1995 borehole velocity profiles (SHB-1). Dacite and site-wide mean horizontal UHRS were also computed. The site-wide UHRS is derived from an envelope of the hazard curves of CMRR, TA-3, TA-16, and TA-55. Table ES-1 lists the horizontal and vertical PGA values for the UHRS.

The new PSHA shows that the horizontal surface PGA values are about 0.5 g at a return period of 2,500 years. The vertical PGA values at the same return period are about 0.3 g. The 1995 horizontal PGA values for a return period of 2,500 years are about 0.33 g. The estimated hazard has increased significantly (including other spectral values) from the 1995 study due to the increased ground motions from the site-specific stochastic attenuation relationships and increase in the activity rate of the PFS. The site response effects as modeled in this study with the newer site geotechnical data appears to amplify ground motions more than in the 1995 analysis. Other factors could be the increased epistemic uncertainty incorporated into the empirical attenuation relationships and in the characterization of the PFS.

Horizontal and vertical DRS for CMRR, TA-3, TA-16, TA-55, dacite, and site-wide were calculated for SDC-3, -4, and -5. Table ES-2 lists the horizontal and vertical PGA values for the DRS. DRS at other dampings levels of 0.5%, 1%, 2%, 3%, 7%, and 10% were computed from the 5%-damped DRS using empirical damping ratios.

Strain-compatible properties including V_S, V_S sigma, S-wave damping, S-wave damping sigma, V_P, V_P sigma, P-wave damping, and strains as a function of depth were calculated for return periods of 2,500 and 10,000 years. The strain-compatible properties are consistent with the mean hazard.

Time histories were developed through spectral matching following the recommended guidelines contained in NUREG/CR-6728. The phase spectra were taken from accelerograms of the 23 November 1980 (1934 GMT) **M** 6.9 Irpinia, Italy, earthquake recorded at the Sturno strong motion site.

Table ES-1
LANL Mean PGA Values (g) From the UHRS

Return Period (years)	CMRR		TA-3		TA-16		TA-55		Site-Wide		Dacite	
	Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.
1,000	0.27	0.32	0.27	0.32	0.25	0.31	0.27	0.32	0.27	0.32	0.13	0.12
2,500	0.52	0.60	0.52	0.59	0.47	0.57	0.52	0.60	0.52	0.60	0.27	0.27
10,000	1.03	1.21	1.03	1.10	0.93	1.05	1.03	1.21	1.03	1.21	0.65	0.65
25,000	1.47	1.79	1.45	1.57	1.33	1.50	1.47	1.79	1.47	1.79	1.01	0.97
100,000	2.30	3.01	2.29	2.79	2.11	2.57	2.30	3.01	2.30	3.01	1.69	1.65

PGA = peak ground acceleration

Table ES-2
LANL PGA Values (g) From the DRS

SDC	CMRR		TA-3		TA-16		TA-55		Site-Wide		Dacite	
	Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.
3	0.47	0.56	0.47	0.53	0.43	0.50	0.47	0.60	0.47	0.56	0.28	0.27
4	0.72	0.87	0.71	0.78	0.65	0.74	0.72	0.86	0.72	0.86	0.47	0.45
5	1.17	1.50	1.17	1.39	1.07	1.29	1.17	1.50	1.17	1.50	0.84	0.82

SDC = Seismic Design Category

Analyses have been updated in three areas. A comprehensive update to the LANL seismic hazards analysis was completed in June 2007 (LANL 2007a), after completion of the 2003 *CMRR EIS*. The updated report used more-recent field study data, most notably from the proposed CMRR-NF site, to update the seismic characterization of LANL, including the probabilistic seismic hazard and horizontal and vertical ground accelerations that would constitute what is considered a design-basis earthquake for the proposed CMRR-NF site. Based on the updated probabilistic seismic hazards analysis, it was concluded that a design-basis earthquake with a return interval of about 2,500 years would have an estimated horizontal peak ground acceleration of 0.52 *g*. The previous estimated horizontal peak ground acceleration for an earthquake with a return interval of about 2,500 years was about 0.3 *g*. As a result of this updated understanding of the seismic hazard, it was concluded that the 2004 CMRR-NF design, as originally conceived, would not survive the updated design-basis earthquake. Therefore, the accident analysis of the 2004 CMRR-NF was updated in this *CMRR-NF SEIS* to reflect the potential consequences and risks associated with such an earthquake. Additionally, analyses of greenhouse gas emissions and the potential impacts of construction transportation on traffic, both of which were not included in the 2003 *CMRR EIS*, have been added to the No Action Alternative analysis.

4.2.2 Land Use and Visual Resources

4.2.2.1 Land Use

Construction and Operations Impacts—Under the No Action Alternative, a total of 26.75 acres (10.8 hectares) would be disturbed during construction of the CMRR Facility (that is, the CMRR-NF and RLUOB) at TA-55. A total of 13.75 acres (5.6 hectares), consisting of land used for buildings (2004 CMRR-NF and RLUOB) and parking lots, would be permanently disturbed. The remaining 13 acres (5.26 hectares) would consist of a construction laydown area (2 acres [0.8 hectares]), an area for a concrete batch plant (5 acres [2 hectares]), and land affected by a road realignment (6 acres [2.4 hectares]). Potential development sites at TA-55 include some areas that have already been disturbed, as well as others that are currently covered with native vegetation, including some mature trees that would have to be cleared prior to construction. Construction and operation of the CMRR Facility at TA-55 would be consistent with the designation of the area for Research and Development and Nuclear Materials Research and Development.

4.2.2.2 Visual Resources

Construction and Operations Impacts—Impacts on visual resources resulting from the construction of the 2004 CMRR-NF at TA-55 under the No Action Alternative would be temporary in nature and could include increased levels of dust and human activity. Once completed, the 2004 CMRR-NF would be one story above ground, and its general appearance would be consistent with current development at LANL. The facility would be readily visible from Pajarito Road and from the upper reaches of the Pajarito Plateau rim. Although the 2004 CMRR-NF would add to the overall development at TA-55, it would not alter the industrial nature of the area. Thus, the current Visual Resource Contrast Class IV rating for TA-55 would not change.

4.2.3 Site Infrastructure

Construction Impacts—Projected annual demands on key site infrastructure resources associated with construction under the No Action Alternative are presented in **Table 4–1**. Existing LANL infrastructure would easily be capable of supporting the construction requirements for the CMRR Facility proposed under this alternative without exceeding site capacities. Although gasoline and diesel fuel would be required to operate construction vehicles, generators, and other construction equipment, fuel would be

Earthquake Report – JAIF

No.15

Status of Fukushima #1 power station as of 06:00, March 20, 2011
"NHK News reports on developments at Fukushima #1 on March 19"

Here is information regarding the status of Fukushima #1 power station. It comes from news reports aired by NHK between 0:00 and 6:00 on March 20.

・The operation for filling the spent fuel pool with water at Unit 3 continued until 03:40 midnight, lasting 13 hours -- 6 hours more than scheduled. The 2000 tons of water-filling operation was done with a special water cannon vehicle in mostly unattended manner to protect the crew against radiation exposure.

・For Units 5 and 6, restored emergency power supply has enabled the cooling system to begin to cool down the spent fuel pond, bringing the Unit 5 pool temperature down from 68.8 ℃ to 43.1℃ at 03:00. Also, the Unit 6 spent fuel pond has seen its water temperature lower 67.5℃ to 52℃ at 03:00.

・At Units 1 and 2, cables were successfully connected to external power supply and TEPCO will make every effort to restore cooling-down capability of the units.

・At Unit 4, the first water-filling operation will be conducted by the Self-Defense Force on March 20. They will use a water cannon truck which enables the crew to stay inside on water filling operation in the high radiation environment.

・Nuclear and Industrial Safety Agency, NISA revealed that radiation monitored at Unit 3 showed 3,443 micro Sv/h at 14:00 March 19 and lowered to 2,906 micro Sv/h. NISA attributes this stable status of the Unit to the water filling.

・According to TEPCO, the maximum acceleration of 507 gal was measured at Unit 3, which exceeds the design basis maximum acceleration of 449 and 441.

507 gal = 0.52 gravity (g)

End

APPENDIX C
EVALUATION OF HUMAN HEALTH IMPACTS FROM FACILITY ACCIDENTS

C.1 INTRODUCTION

Accident analyses were performed to estimate the impacts to workers and the public from reasonably foreseeable accidents for the Los Alamos National Laboratory (LANL) Chemistry and Metallurgy Research Building Replacement (CMRR) project alternatives. The analyses were performed in accordance with U.S. Department of Energy (DOE) National Environmental Policy Act (NEPA) guidelines, including the process followed for the selection of accidents, definition of accident scenarios, and estimation of potential impacts. The sections that follow describe the methodology and assumptions, accident selection process, selected accident scenarios, and consequences and risks of the accidents evaluated.

C.2 OVERVIEW OF METHODOLOGY AND BASIC ASSUMPTIONS

The radiological impacts from accidental releases from the facilities used to perform chemistry and metallurgy research (CMR) operations were calculated using the MACCS computer code, Version 1.12 (MACCS2). A detailed description of the MACCS model is provided in NUREG/CR-6613. The enhancements incorporated in MACCS2 are described in the *MACCS2 Users Guide* (NRC 1998). This section presents the MACCS2 data specific to the accident analyses. Additional information on the MACCS2 code is provided in Section C.8.

As implemented, the MACCS2 model evaluates doses due to inhalation of airborne material, as well as external exposure to the passing plume. This represents the major portion of the dose that an individual would receive because of a facility accident. The longer-term effects of radioactive material deposited on the ground after a postulated accident, including the resuspension and subsequent inhalation of radioactive material and the ingestion of contaminated crops, were not modeled for this environmental impact statement (EIS). These pathways have been studied and found to contribute less significantly to the dosage than the inhalation of radioactive material in the passing plume; they are also controllable through interdiction. Instead, the deposition velocity of the radioactive material was set to zero, so that material that might otherwise be deposited on surfaces remained airborne and available for inhalation. Thus, the method used in this EIS is conservative compared with dose results that would be obtained if deposition and resuspension were taken into account.

The impacts were assessed for the offsite populations surrounding each candidate site for the new CMRR Facility and the existing CMR Building, as well as a maximally exposed offsite individual, and noninvolved worker. The impacts to involved workers, those working in the facility where the accident occurs, were addressed qualitatively because no adequate method exists for calculating meaningful consequences at or near the location where the accident could

(0.6 kilograms) of plutonium-239 liquid. The frequency of the accident is estimated to be in the range of 0.000001 to 0.00001 per year and is conservatively assumed to be 0.00001 per year for risk calculation purposes.

Facility-Wide Spill—An earthquake is postulated to occur that exceeds the Performance Category-3 design capability of the facility. A vault and process areas containing radioactive material are severely damaged and their plutonium-239 contents in the form of powder spills. The material at risk is estimated to be 13,230 pounds (6,000 kilograms) of plutonium-239 in powder form. The scenario conservatively assumes the damage ratio and leak path factors are 1.0. No credit is taken for equipment and facility features and mitigating factors that could cause the damage ratio and leak path factors to be less than 1.0. The released respirable fraction (airborne release fraction times respirable fraction) is estimated at 0.002 for powder. The source term for radioactive material released to the environment is 26.461 pounds (12 kilograms) of plutonium-239 powder. The frequency of the accident is estimated to be less than 5.0×10^{-6} and is conservatively assumed at 5.0×10^{-6} per year for risk calculation purposes.

C.4.2 No Action Alternative

The accidents described in this section pertain to the No Action Alternative.

Wing-Wide Fire—The accident scenario postulates combustibles in the vicinity of an ignition source are ignited in a laboratory area containing the largest amounts of radioactive materials. The fire is assumed to propagate uncontrolled and without suppression to adjacent laboratory areas an entire facility wing. The material at risk is estimated at 13.23 pounds (6 kilograms) of plutonium-239 equivalent in the form of metal (20 percent), powder (40 percent) and solution (40 percent). The scenario conservatively assumes the damage ratio and leak path factors are 1.0, and the released respirable fraction (airborne release fraction times respirable fraction) is estimated at 0.017. The frequency of the accident is estimated to be 0.00005 per year.

HEPA Filter Fire—A fire or deflagration is assumed to occur in the HEPA filters due to an exothermic reaction involving reactive lasts or other materials. Two filters containing 0.18 ounces (5 grams) of plutonium-239 equivalent each are affected. The material at risk is estimated at 0.35 ounces (10 grams) of plutonium-239 equivalent in the form of oxide particles. The damage ratio and leak path factors are conservatively assumed at 1.0 and the released respirable fraction (airborne release fraction times respirable fraction) is estimated at 0.4. The resulting source term of radioactive material released to the environment is estimated at 0.14 ounces (4 grams) of plutonium-239 equivalent. The frequency of the accident is estimated to be in the range of 0.0001 to 0.01 and is conservatively assumed to be 0.01 per year for risk calculation purposes.

Fire in the Main Vault—This accident postulates a fire in the main vault. In this scenario, the main vault door is accidentally left open and a fire inside the vault or propagating to the main vault engulfs the entire contents of plutonium. The material at risk is estimated at 440.92 pounds (200 kilograms) of plutonium-239 equivalent. The damage ratio and leak path factors are conservatively assumed at 1.0 and the released respirable fraction (airborne release fraction times respirable fraction) is estimated at 0.002. The resulting source term of radioactive material

Management and Disposition of Excess Weapons Plutonium (1994)
Office of International Affairs (OIA)

1

Introduction: Task and Context

THE TASK

With the end of the Cold War, the world is faced for the first time with the need to manage the dismantlement of vast numbers of "excess" nuclear weapons and the disposition of the fissile materials they contain. If recently agreed reductions are fully implemented, tens of thousands of nuclear weapons, containing a hundred tons or more of plutonium and many hundreds of tons[1] of highly enriched uranium (HEU), will no longer be needed for military purposes. These two materials are the essential ingredients of nuclear weapons, and limits on access to them are the primary technical barrier to acquiring nuclear weapons capability in the world today. Several kilograms of plutonium, or several times that amount of HEU, are sufficient to make a nuclear weapon.[2] These materials will continue to pose a potential threat to humanity for as long as they exist.

The task of managing this reversal of the arms competition is complicated by the breakup of the Soviet Union and the continuing political and economic

[1] Throughout this report metric tons (MT) are used as the measure of the amounts of plutonium and HEU; all references to tons are to metric tons. One metric ton is 2,205 pounds, roughly 10 percent more than an English ton.

[2] For purposes of this study, 4 kilograms of plutonium per weapon will be used as a planning figure. The minimum quantities of plutonium or HEU needed to make a weapon are not well defined, since they depend on the design. Actual quantities used in U.S. weapons are classified.

19

Below are the first 10 and last 10 pages of uncorrected machine-read text (when available) of this chapter, followed by the top 30 algorithmically extracted key phrases from the chapter as a whole.
Intended to provide our own search engines and external engines with highly rich, chapter-representative searchable text on the opening pages of each chapter. Because it is UNCORRECTED material, please consider the following text as a useful but insufficient proxy for the authoritative book pages.

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OCR for page 19
1 Introduction: Task and Context THE TASK With the end of the Cold War, the world is faced for the first time with the need to manage the dismantlement of vast numbers of "excess" nuclear weapons and the disposition of the fissile materials they contain. If recently agreed reductions are fully implemented, tens of thousands of nuclear weapons, containing a hundred tons or more of plutonium and many hundreds of tonsi of highly enriched uranium (HEU), will no longer be needed for military pur- poses. These two materials are the essential ingredients of nuclear weapons, and limits on access to them are the primary technical barrier to acquiring nu- clear weapons capability in the world today. Several kilograms of plutonium, or several times that amount of HEU, are sufficient to make a nuclear weapon.2 These materials will continue to pose a potential threat to humanity for as long as they exist. The task of managing this reversal of the arms competition is complicated by the breakup of the Soviet Union and the continuing political and economic ~ Throughout this report metric tons (MT) are used as the measure of the amounts of plutonium and HEU; all references to tons are to metric tons. One metric ton is 2,205 pounds, roughly 10 percent more than an English ton. 2 For purposes of this study, 4 kilograms of plutonium per weapon will be used as a planning figure. The minimum quantities of plutonium or HEU needed to make a weapon are not well defined, since they depend on the design. Actual quantities used in U.S. weapons are classified. 19

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20 INTRODUCTION: TASK AND CONTEXT crises in the former Soviet states. There are substantial risks that more than one nuclear state could arise from the former Soviet Union, that the recently agreed arms reductions could stall, and that control over nuclear weapons or fissile materials could erode, increasing the danger that they would fall into the hands of unauthorized parties. Urgent actions are required to secure and account for these weapons and materials. The task is pressing, but the solutions will be complex, expensive, and long-term. The process can be divided into three distinct but overlapping phases: dismantlement of nuclear weapons, intermediate storage of fissile ma- terials, and long-term disposition of those materials.3 Figure 1-1 outlines the policy choices at each stage; Figure 1-2 gives an idea of the time scales in- volved. For each of these stages, critical policy choices must be made, with wide-ranging implications for both arms reduction and nonproliferation. In- deed, without new approaches to managing the reductions process, it is unlikely that long-term U.S. arms reduction and nonproliferation objectives can be achieved. Dismantlement of weapons and storage of the resulting fissile materials are already under way. Final disposition of the materials will take far longer to ac- complish. The HEU from nuclear weapons can be blended to make a reactor fuel that poses little proliferation risk and can return a substantial economic benefit, but disposition of weapons plutonium is far more problematic; hence, plutonium is the primary focus of this report. There are no easy answers to the plutonium problem. Policymakers will have to choose from a variety of imper- fect options, requiring inherently judgmental trade-offs among different cate- gories of risks. It will be more than a decade before any of the plausible options for long- term disposition of weapons plutonium makes a substantial dent in the likely excess stockpile. Most of the options would require 20 to 40 years to accom- plish the task.4 Although use of HEU as reactor fuel could return a profit large enough to pay for most of the tasks just described, all of the options for disposi- tion of plutonium are likely to involve net economic costs, not net benefits, because in the current market plutonium is a more expensive reactor fuel than widely available uranium (see "The Value of Plutonium," p. 241. Thus pluto- nium disposition is fundamentally a problem of security, far more than one of efficient utilization of assets. Exploiting the energy value of plutonium should not be a central criterion for decision, both because plutonium cannot compete economically with uranium in the current market, and because whatever eco- nomic value this plutonium might represent now or in the future is small by 3 The processes of retiring the nuclear weapons from active duty, disabling them, bringing them to dismantlement sites (if necessary, from foreign deployment), and retiring or dismantling the launchers involved are also critical parts of the arms reduction process, but are beyond the scope of this report. 4 Even in the simpler case of HEU, which the United States plans to purchase from the states of the former Soviet Union for use as nuclear fuel, the planned transfer still being negotiated would extend over 20 years.

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INTRODUCTION: TaSK AND CONTEXT 21 Total Stocks '~Declarations & Monitoring (Reciprocal, Unilateral, None) of Weapons & Agreement on Reductions, Limits on Additions (Reciprocal, Unilateral, None) Fissile Materials Security and Accounting Improvements (National, Cooperative) Weapons - ~Monitoring (Reciprocal, Unilateral, None) Dismantlement Intermediate Storage Technical Intact Pits Deformed Pits Oxides Ingots Others Indefinite Storage Long-Term Disposition Minimized Storage Elimination FIGURE 1-1 Phases of plutonium management - Institutional Who Safeguards? Who Protects? Who Owns? Who Finances? Where Located? Reactors (without reprocessing) Disposal Vitrification, Borehole, Seabed, Underground Explosion, etc. Reactors (with reprocessing-includes accelerator-driven reactors) Disposal Space Launch Ocean Dilution comparison to the security stakes. The cost of management and disposition of weapons plutonium must be seen as an investment in security, just as the cost of its production was once viewed. All of the options for long-term plutonium disposition will require many years to complete. Thus, storing this material is the only available near-term option. The United States and Russia must quickly develop appropriate techni- cal and institutional arrangements for dismantlement and storage, following through on the discussions already under way. Judgments about the most desir- able immediate approaches for these tasks must necessarily be based on condi- tions that exist or can be readily foreseen today. At the same time, these storage arrangements must be designed to endure for decades. Planning for long-term disposition of plutonium will inevitably involve more uncertain extrapolations of risks although because of the longer time involved, it will also be easier to make corrections in planning over time. Thus, this report does not provide a single definitive answer for the disposition phase

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INTRODUCTION: TASK AND CONTEXT 23 of the plutonium problem. Instead it offers a road map, whose objective is to provide guidelines for the necessary national debate to come and to focus fur- ther efforts on those options most likely to minimize future risks. Such a road map can help avoid wasting resources on options with little promise and can provide plausible end points for the process that the near-term steps will set in motion. Developing a broad consensus on such a road map deserves high . . pnonty. OBJECTIVES The primary goal in choosing options for management and disposition of excess nuclear weapons and fissile materials should be to minimize the risks to national and international security posed by the existence of this material. This security goal can be divided into three main objectives: 1. to minimize the risk that weapons or fissile materials could be obtained by unauthorized parties; 2. to minimize the risk that weapons or fissile materials could be reintroduced into the arsenals from which they came, halting or reversing the arms reduc- tion process; and 3. to strengthen the national and international control mechanisms and incen- tives designed to ensure continued arms reductions and prevent the spread of nuclear weapons. In addition to these security objectives, all options must protect worker health and the environment, and be acceptable to the public. Timing, which plays an important part in whether the security criteria can be met, and consis- tency with other policies and objectives will also be important criteria for choice.5 Cost will inevitably also be an important consideration. The committee notes, however, that the expenditures implied by all its recommendations com- bined would total at most several billion dollars, spread over a period of a dec- ade or decades. Since the primary objective is the reduction of major security risks, these expenditures should be considered in the context of the far larger sums being expended every year to provide national and international security. Thus, cost should not be the primary criterion in choosing among competing options. The most immediate threat to all three of the security objectives is only partly related to the management and disposition of excess weapons and fissile materials. This is the possibility that more than one nuclear state may emerge from the breakup of the Soviet Union. Ukraine is the greatest apparent risk. 5 For more detail on the criteria for choice, see Chapter 3; for more detail on how a regime Thor management and limitation of weapons and fissile materials could affect the security objectives, see Chapter 4.

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26 INTRODUCTION: TASK AND CONTEXT President Leonid Kravchuk, in the Lisbon Protocol of 1992 and an accompany- ing letter, established a formal international commitment to denuclearization. But that commitment remains the subject of intense debate in Ukraine, bringing the implementation of current strategic arms reduction agreements into ques- tion. In November 1993, the Ukrainian Rada voted to ratify the first Strategic Arms Reduction Treaty (START IJ without accepting the denuclearization commitment, explicitly exempting more than half of the missiles on Ukrainian soil from elimination. Efforts to resolve this issue are continuing, and Kravchuk has said he will resubmit the agreement to a new parliament in 1994. If Ukraine actually reversed its commitment and attempted to acquire an inde- pendently controlled nuclear arsenal, the entire framework of nuclear arms reduction and nonproliferation would be severely, perhaps fatally, damaged. Security concerns may well be the driving factors in Ukraine's ultimate deci- sion, but that decision could be affected by measures to ensure that weapons and fissile materials transferred to Russia will not be reused for military pur- poses, and to provide compensation for these materials. Beyond that immediate issue, decisions about excess nuclear weapons and fissile materials are likely to have far-reaching consequences for each of the three security goals just described: The Risk of Theft.6 Restricting access to fissile material is the principal technical barrier to proliferation in today's world, far more so than access to the information and technologies needed to build a weapon once the fissile material has been acquired. This makes the task of securing weapons and fissile materi- als critical.7 The risk that nuclear weapons or fissile materials could fall into unauthorized hands whether through theft, sale, or other means-can be re- duced by steps taken singly and jointly to keep strict accounting of these mate- rials; to improve their security; to strengthen the organizations responsible for their management; and to dismantle weapons and transfer the resulting mate- rials into secure, monitored storage and ultimately to civilian use or disposal. In addition, a well-designed regime to carry out such steps could provide a new and compelling mission for the organizations once charged with producing nuclear weapons, reducing the risks that control could erode. The Risk of Reversal. Even after the START I and START II agreements enter into force and the reductions they call for are implemented, as long as the retired warheads and the material they contain remain in usable form, the risk 6 although in many contexts the term "diversion" is used to mean any case in which an unauthorized party obtains a particular item, in the parlance generally employed in international nonproliferation efforts, particularly by the International Atomic Energy Agency (L\EA), a distinction is made between "diversion" and "theft." Diversion refers to the state that owns material under safeguards removing it for weapons purposes, whereas theft refers to acquisition of these materials by other unauthorized parties. This report follows that convention. 7 The current concern about North Korea's possible possession of several kilograms of separated plutonium highlights the importance of tight controls over these materials.

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INTRODUCTION: TASK AND CONTEXT 27 will remain that one of the parties may decide to rebuild its nuclear arsenal in contravention of its agreements and pledges. The retired weapons could be used directly, or the materials from them could be used to fabricate new warheads. This risk could be reduced by agreements designed to make such a rearmament program more difficult, time-consuming, costly, and easily detected. These could include agreements to verifiably dismantle the weapons, to create barriers to reusing the resulting fissile material for new weapons, and to improve trans- parency for the stocks of nuclear weapons and fissile materials. Strengthening Arms Reduction and Nonproliferation. The current arms reduction regime would be politically strengthened by appropriate measures to increase transparency and cooperation in managing excess weapons and fissile materials. Such measures would help convince doubters worldwide, including those in the United States, Russia, and Ukraine, that the arms reduction regime serves the interests of all parties. Credible controls and transparency would also provide a critical foundation for pursuing deeper reductions, and for

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1946 TO THE PRESENT

(RDD-8)

January 1, 2002

U.S. Department of Energy
Office of Health, Safety and Security
Office of Classification

Contains information which may be exempt from public release under the Freedom of Information Act (5 U.S.C. 552), exemption number(s) 2. Approval by the Department of Energy prior to public release is required.

Reviewed by: Richard J. Lyons Date: 3/20/2002

NOTICE

This document provides historical perspective on the sequence of declassification actions performed by the Department of Energy and its predecessor agencies. It is meant to convey the amount and types of information declassified over the years. Although the language of the original declassification authorities is cited verbatim as much as possible to preserve the historical intent of the declassification, **THIS DOCUMENT IS NOT TO BE USED AS THE BASIS FOR DECLASSIFYING DOCUMENTS AND MATERIALS** without specific authorization from the Director, Information Classification and Control Policy. Classification guides designed for that specific purpose must be used.

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Name/Org.: Andrew P. Weston-Dawkes, HS-90
Date: March 12, 2009

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II. MATERIALS (Continued)

the pit of unspecified staged weapons. (93-2)

33. Special nuclear materials masses: That about 6 kg plutonium is enough hypothetically to make one nuclear explosive device. (93-2)

    a. Hypothetically, a mass of 4 kilograms of plutonium or uranium-233 is sufficient for one nuclear explosive device. (94-1)

    NOTE: The average masses of special nuclear materials in the U.S. nuclear weapons or special nuclear materials masses in any specific weapon type remain classified.

34. The total quantities of plutonium produced or processed at Richland. (93-3)

35. The total quantity of weapons grade plutonium including supergrade plutonium produced at the Savannah River Plant. (93-5)

36. The Savannah River approximate total post-August 1988 plutonium inventory. (93-6)

37. The United States total production of weapon-grade plutonium. (93-7)

38. The current plutonium inventory at the Rocky Flats Plant. (93-8)

39. The current total plutonium inventory at the Argonne National Laboratory-West. (93-8)

40. The current total plutonium inventory at the Los Alamos National Laboratory and the Lawrence Livermore National Laboratory. (93-8)

41. The quantity of plutonium involved in the fire in Room 180 in Building 771 on September 11, 1957, and the quantity of plutonium involved in the fire in Buildings 776 and 777 on May 11, 1969, as represented by inventory data, the amount recovered, the amounts allocated to other disposition categories such as normal operating loss, and the amount considered inventory difference *as long as weapon design, manufacturing, material composition or properties, or other classified information that is protected by classified inventory data is not revealed.* (94-5)

42. The historical (1952 - 1993) annual inventory difference for plutonium and highly enriched uranium at Rocky Flats. (94-7)

43. The historical quantity of plutonium produced for any time period in the Savannah River reactors and information that only reveals Pu production. (94-9)

IV. ASSESSMENT OF FY 2008 PERFORMANCE

PBI NO. 1 MULTI-SITE PERFORMANCE

PBI 1: Multi-Site Performance

Maximum Available Fee: **$5,129,600**
Fee Earned: **$5,129,600**

PBI 1: Multi-Site Performance		AVAILABLE FEE $5,129,600		AWARDED FEE $5,129,600 100%	
		BASE	STRETCH	BASE	STRETCH
1.1	Down-Select W76 Life Extension Program (LEP) Canned Sub-Assembly (CSA) Material	$674,947	$0	$674,947	$0
1.2	Deliver B61-7/11 LEP Quantities to DoD On Time Per P&PD	$539,958	$0	$539,958	$0
1.3	Approve W88 SS-21 HAR	$134,989	$0	$134,989	$0
1.4	Complete Complex Transformation NEPA Process by August 2008	$67,495	$0	$67,495	$0
1.5	Deleted	$0	$0	$0	$0
1.6	Match 2007 Dismantlements	$269,979	$0	$269,979	$0
1.7	Deliver Products for DoD On Time Per P&PD	$674,947	$0	$674,947	$0
1.8	Implement a NNSA Supply Chain Management Center (SCMC)	$202,485	$0	$202,485	$0
1.9	Implement Gas Sampling Activities Using Powerless Pump Module	$134,989	$0	$134,989	$0
1.10	Implement Elements from FY 2007 Developed Multi-Site Enterprise IT Plan	$202,485	$0	$202,485	$0
1.11	Implement Requirements Modernization Initiative (RMI) Phase II Implementation	$202,485	$0	$202,485	$0
1.12	Implement Advanced Simulation and Computing (ASC) Tri-Lab Productivity on Demand (TriPod) Initiative by September 30, 2008	$269,979	$0	$269,979	$0
1.13	Build Six New W88 Pits & Install Equipment in FY 2008 to Increase Pit Capacity to 80 Pits Per Year by the Operational Date of a CMRR-Nuclear Facility	$1,079,915	$0	$1,079,915	$0
1.14	Reduce Uncertainty in Warhead Performance	$269,979	$0	$269,979	$0
1.15	Remove 11 Metric Tons of SNM from NNSA Sites by September 30, 2008	$404,968	$0	$404,968	$0
		$5,129,600	$0	$5,129,600	$0

Completion/Validation Statements

Measure 1.1 Down-Select W76 Life Extension Program (LEP) Canned Sub-Assembly (CSA) Material (Incentive/Base)

Expectation Statement:
Down-select W76 Life Extension Program (LEP) Canned Sub-Assembly (CSA) material.

Completion Assessment:
LANS has submitted completion evidence for award of full fee. NNSA has validated appropriate and timely completion.

Measure 1.13 Build Six New W88 Pits & Install Equipment in FY 2008 to increase Pit Capacity to 80 Pits per Year by the Operational Date of a CMRR-Nuclear Facility (Incentive/Base)

Expectation Statement:
Build six new W88 pits and install equipment in FY 2008 to increase pit capacity to 80 pits per year by the operational date of a CMRR-Nuclear facility.

Completion Assessment:
LANS has submitted completion evidence for award of full fee. NNSA has validated appropriate and timely completion.

Measure 1.14 Reduce Uncertainty in Warhead Performance (Incentive/Base)

Expectation Statement:
Reduce Uncertainty in warhead performance.

Completion Assessment:
LANS has submitted completion evidence for award of full fee. NNSA has validated appropriate and timely completion.

Measure 1.15 Remove 11 Metric Tons of SNM from NNSA Sites by September 30, 2008 (Incentive/Base)

Expectation Statement:
Remove 11 metric tons of SNM from NNSA sites by September 30, 2008.

Completion Assessment:
LANS has submitted completion evidence for award of full fee. NNSA has validated appropriate and timely completion.

United States Government Accountability Office

GAO

Report to the Subcommittee on Energy and Water Development, Committee on Appropriations, House of Representatives

May 2008

NUCLEAR WEAPONS

NNSA Needs to Establish a Cost and Schedule Baseline for Manufacturing a Critical Nuclear Weapon Component

G A O

Accountability * Integrity * Reliability

GAO-08-593

LANL's Existing Facility for Analyzing Pit Samples Has Major Operational Limitations

LANL analyzes plutonium from pit subcomponents, feed materials, and waste streams for a variety of purposes. These analyses provide the (1) data required to certify the material control and accountability of the plutonium feed and waste materials, (2) chemical accuracy for quality control of the product, and (3) assurance that the pit will meet its performance specifications. The CMR building, which was constructed in the early 1950s, houses most of LANL's analytical chemistry capabilities. According to LANL estimates, for each pit that is produced at PF-4, the pit manufacturing program generates an average of about 10 to 15 samples that have to be sent to CMR for analytical chemistry analyses. Chemists at CMR take each sample and conduct multiple analyses or "instrument runs." As a result, each pit generates an average of about 100 to 150 instrument runs at CMR.

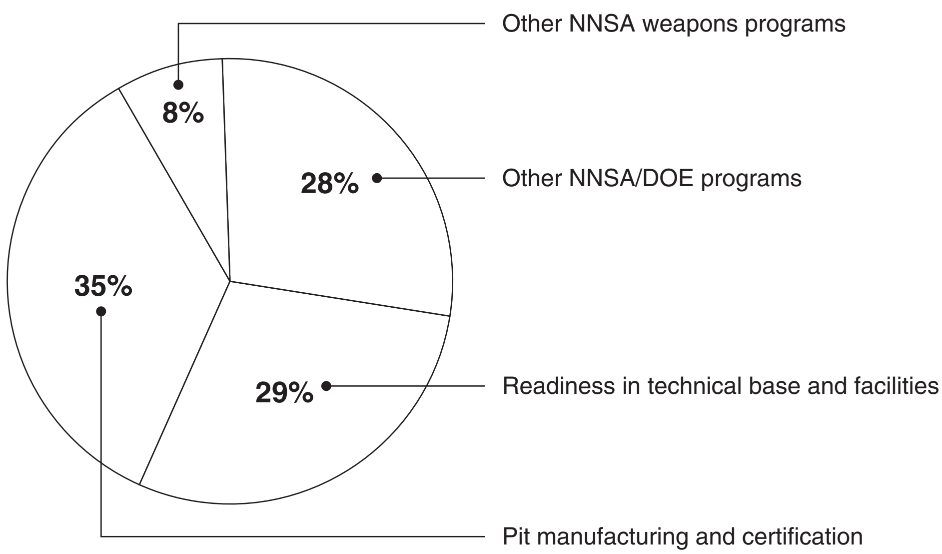
According to LANL estimates, CMR currently contains enough analytical chemistry instruments to support a pit production rate of 20 pits per year. However, because of several limiting factors, LANL officials estimate that the CMR building can only support a pit production capacity of between 10 to 15 pits per year. The major factor limiting analytical chemistry operations in CMR is the need to impose safety restrictions on CMR's operations that involve plutonium. In 1992, DOE began a planning process aimed at upgrading many of the safety, security, and safeguards features of CMR. Later, in 1997 and 1998, a series of operational, safety, and seismic issues surfaced that affected the long-term viability of CMR. For example, studies identified a seismic fault trace beneath one of the wings of the CMR building that increased the level of structural integrity required to meet current structural seismic code requirements for a Hazard Category 2 nuclear facility.[9]

DOE decided that it would be too difficult and costly to correct the CMR building's defects by performing repairs and upgrades. Instead, DOE decided to perform only the upgrades necessary to ensure the safe and reliable operation of the CMR building through 2010. In addition, LANL imposed a number of restrictions on the CMR facility's operations and capabilities. For example, the areas within CMR that perform analytical

[9]DOE defines the CMR building as a Hazard Category 2 nuclear facility, which is one in which a hazard analysis identified the potential for significant on-site consequences. A hazard analysis is the determination of material, system, process, and plant characteristics that can produce undesirable consequences. The hazard analysis examines the complete spectrum of potential accidents that could expose members of the public, on-site workers, facility workers, and the environment to hazardous materials.

and maintenance and addressing environment, safety, and health issues. The remaining 36 percent of available space in PF-4 is used by other programs. (See table 4 for a description of these programmatic areas.)

Figure 2: Percentage of Space in PF-4 Occupied by Various Programs as of September 1, 2007



Source: LANL.

Table 4: Description of Programmatic Areas Occupying Space in PF-4

Program	Description
Other NNSA weapons programs	
Pit surveillance	This program takes pits from the stockpile and subjects them to destructive and nondestructive tests to ensure that no changes that might affect performance are occurring in the pits.
Plutonium research and development	This program supports all defense-related programs by maintaining the capability to address new and unusual issues that arise during the execution of the other plutonium-related programs.
Special recovery line	This program processes retired stockpile components to recover tritium-contaminated plutonium.
Other NNSA/DOE programs	
Pu-238 heat source fabrication	This program designs and fabricates general purpose heat source units and radioisotope heater units for the National Aeronautics and Space Administration.

Report of the Nuclear Weapons Complex Infrastructure Task Force

Recommendations for the Nuclear Weapons Complex of the Future

July 13, 2005
Draft Final Report

Secretary of Energy Advisory Board
U.S. Department of Energy

Options for the MPF

Several ideas that should be considered before they are discarded, since the savings are large for each option, and several of the options could result in additive savings:

- Reduce the structure costs to meet the DBT by using (buying) more land, obtaining advantage of earlier detection and thereby denying approach.
- Consider placing the process building underground.
- Consider placing of the process building inside of a mountain.
- Review the DOE DBT and see if there are other technologies that can be deployed to reduce the cost of the building and still achieve the DBT requirements, but at lower capital and operating cost.
- The size of the MPF is scaled by the production rate of 125 per year. If that number could be reduced by ½ the footprint of the production building should scale, but not quite linearly.
- Reduce the types of pits to be produced. Designing for pits of the future rather than the unique and hard to make pits of the Cold war stockpile would save a lot of money.

It is the Study Group's opinion that the last bullet may have the greatest impact on capital cost reduction, from a technical perspective.

The DBT, which is not a technical requirement, also drives the cost. The Study Group believes that constructing underground, in a mine, or an equivalent, could be the cheapest method to address the DBT is burial. Traditional mining companies can profitably mine underground ore valued at $200/cubic yard. Thus, ~ $50 M should provide a substantially subsurface cavity to house a "thin walled" pit manufacturing facility or any other equivalent type work space.

SRS has utilized good engineering practices and teamwork in the MPF project to date. SRS developed a scope of work, a "model", and established a design criteria and production output level. SRS has designed the MPF given the current set of regulations, guidelines, DBT, safety considerations at today's standards. If these standards or other factors change, it will only make this facility more difficult to build and more costly, if it is done in the traditional DOE manner. It should also be recognized that construction raw material costs are escalating higher on a daily basis. This will also drive project costs higher. Consideration should be given to spend more time and effort on the "Design" phase to reduce contingency and uncertainty in the cost estimate.

TA-55 Operations Commentary

TA-55 is a remarkable facility. The attention to detail at every level of manufacture is to be commended. It is obvious that **processes have been laboriously developed** to provide a quality product safely. However, the manufacturing priorities appear to be: (1) Safety, (2) Security, (3) Quality. **The one missing element is: Productivity**.

Due to the nature of the processes, safety and security requirements must take a priority. This is obvious a given a facility of this critical nature. Unfortunately, the manufacturing operation at TA-55 is extremely inefficient when compared with any conventional manufacturing operation. There is little evidence of modern manufacturing techniques being employed. The fundamental process design is grounded in a seriously outdated "inspect quality in" mentality. Modern manufacturing techniques including Lean Manufacturing, Six Sigma, Design of Manufacturability and Assembly, and others, if applied rigorously could yield unprecedented reductions in TA-55 pit manufacturing costs and cycle time.

The enormous investment made in the TA-55 facility has not yielded anywhere near the productivity levels this facility should be capable of attaining. The process is operated with little sense of urgency. It appears that each manufacturing step is "an event" attracting numerous witnesses and visitors. The process of actually building a pit seems to be a secondary mission of the facility, not the primary focus.

At every phase of operation, there appears to be numerous opportunities to "lean-out" the operation. The current process follows 1950's "inspect in" quality methodology. As such, the vast majority of the time the plutonium material, raw or in the process of becoming a pit, is waiting to be inspected, to be tested, waiting for test results, etc. This is an incredible waste of time. This is not to say that quality inspection does not have its place, it does. But given the many years of pit manufacturing experience, we should know how to make these components by well characterized processes which should not require the current amount of sequential testing which absolutely kills productivity. At a minimum, a rigorous review to determine necessary testing requirements would be valuable. In addition, current analytical metrology techniques, if applied, should yield superior results in much shorter time frames.

Lean Manufacturing techniques such as Value Stream Mapping could easily be applied to the pit manufacturing process. Fundamentally, the pit facility produces one product, yet it appears that every pit produced is a "hand crafted individual object". This method of production yields process inefficiencies in **every** operation. Additionally, process automation at several steps of this process would be quite valuable. Currently available CNC machining centers, modified for the unique safety hazards would yield a wealth of productivity gains.

From a modern industry standpoint, world class productivity, quality, and safety can all be attained at the TA-55 facility by thorough and rigorous analysis and hard work on the production floor. The cursory analysis of the TA-55 facility yields a ratio of value-added to non-value-added work of perhaps 1:20 or much worse. This indicates a tremendous opportunity for improvement. The available productive capacity of this plant is being wasted by inefficient utilization of plant equipment and personnel.

In conclusion, the TA-55 facility is an expensive national asset, which has the opportunity to be a dramatically more effective and efficient facility if operated as a modern production facility, utilizing available automation and world class operations management techniques.

11-D-801, TA-55 Reinvestment Project – Phase II (TRP II)
Los Alamos National Laboratory (LANL), Los Alamos, New Mexico
Project Data Sheet (PDS) is for Construction

1. Significant Changes

The most recent DOE O 413.3B approved Critical Decision (CD) is CD-1, Approve Alternative Selection and Cost Range for all three phases of TRP II that was approved on July 15, 2008 with a preliminary cost range of $75,400 to $99,900 and a preliminary CD-4 date of FY 2016.

Phase A: Glovebox #1 and Air Dryers
The most recent DOE O 413.3B approved CD is CD-2 for Phase A, Approve Performance Baseline that was approved on November 24, 2009 with a Total Project Cost (TPC) of $19,470 and a CD-4 date of May 2013.

Phase B: Glovebox #2, Confinement Doors, and Demolition of Plutonium Facility (PF)-7 in support of the Uninterruptible Power Supply (UPS)
The most recent DOE O 413.3B approved CD is CD-2 for Phase B, Approve Performance Baseline that was approved on June 3, 2010 with a TPC of $18,203 and a CD-4 date of February 2014.

Phase C: Glovebox #3, Exhaust Stack, UPS, Criticality Alarm System, and Vault Water Tanks
The most recent DOE O 413.3B approved CD is CD-1, Approve Alternative Selection and Cost Range that was approved on July 15, 2008 with a TPC not to exceed $66,227. A performance baseline (CD-2) is anticipated by the 3Q FY 2011.

This phased critical decision approach and schedule is consistent with the tailoring strategy that has been approved by the NNSA Acquisition Executive.

As stated in the FY 2010 President's Budget Request, (06-D-140 data sheet), "construction and final design funding for TRP II will be requested in the future via a new PDS." This data sheet meets that commitment and includes the TRP II final design scope and funding.

A Federal Project Director at the appropriate level has been assigned to this project.

This PDS is an update to the FY 2011 PDS. Project progress is noted in Section 2 below.

2. Design, Construction, and D&D Schedule

(fiscal quarter or date)

	CD-0	CD-1	PED Complete	CD-2	CD-3	CD-4	D&D Start	D&D Complete
FY 2011	3/23/2005	7/15/2008	3QFY2012	TBD	TBD	TBD	N/A	N/A
FY 2012	3/23/2005	7/15/2008	3QFY2012	TBD	TBD	TBD[a]	N/A	N/A

Phase A: Glovebox #1 and Air Dryers

(fiscal quarter or date)

	CD-0	CD-1	PED Complete	CD-2	CD-3	CD-4	D&D Start	D&D Complete
FY 2011	3/23/2005	7/15/2008	3QFY2012	11/24/2009	1QFY2010	3QFY2013	N/A	N/A
FY 2012	3/23/2005	7/15/2008	2QFY2011	11/24/2009	4QFY2011	3QFY2013	N/A	N/A

Phase B: Glovebox 2, Confinement Doors, and Demolition of PF-7 in support of the UPS

(fiscal quarter or date)

	CD-0	CD-1	PED Complete	CD-2	CD-3	CD-4	D&D Start	D&D Complete
FY 2011	3/23/2005	7/15/2008	3QFY2012	3QFY2010	TBD	TBD	N/A	N/A
FY 2012	3/23/2005	7/15/2008	4QFY2011	6/3/2010	4QFY2011	2QFY2014	N/A	N/A

Phase C: Glovebox 3, Exhaust Stack, UPS, Criticality Alarm System, and Vault Water Tanks

(fiscal quarter or date)

	CD-0	CD-1	PED Complete	CD-2	CD-3	CD-4	D&D Start	D&D Complete
FY 2011	3/23/2005	7/15/2008	3QFY2012	3QFY2011	TBD	TBD	N/A	N/A
FY 2012	3/23/2005	7/15/2008	3QFY2012	3QFY2011	TBD	TBD	N/A	N/A

CD-0 – Approve Mission Need
CD-1 – Approve Alternative Selection and Cost Range
CD-2 – Approve Performance Baseline
CD-3 – Approve Start of Construction
CD-4 – Approve Start of Operations or Project Closeout
D&D Start – Start of Demolition & Decontamination (D&D) work
D&D Complete –Completion of D&D work

[a] Preliminary estimate for CD-4 is FY 2016.

3. Baseline and Validation Status

(dollars in thousands)

	TEC, Prelim Design	TEC, Final Design	TEC, Construction	TEC, Total	OPC Except D&D	OPC, D&D	OPC, Total	TPC
FY 2011	13,684	TBD	TBD	TBD	TBD	N/A	TBD	TBD
FY 2012	14,684	12,700	56,715	84,099	15,477	N/A	15,477	99,576

Phase A: Glovebox #1 and Air Dryers

(dollars in thousands)

	TEC, Prelim Design	TEC, Final Design	TEC, Construction	TEC, Total	OPC Except D&D	OPC, D&D	OPC, Total	TPC
FY 2011	3,700	TBD	15,330	19,030	440	N/A	440	19,470
FY 2012	4,289	1,848	12,448	18,585	443	N/A	443	19,028

Phase B: Glovebox 2, Confinement Doors, and Demo of PF-7 in support of the UPS

(dollars in thousands)

	TEC, Prelim Design	TEC, Final Design	TEC, Construction	TEC, Total	OPC Except D&D	OPC, D&D	OPC, Total	TPC
FY 2012	5,069	854	11,041	16,964	621	N/A	621	17,585

Phase C: Glovebox 3, Exhaust Stack, UPS, Criticality Alarm System, and Vault Water Tanks

(dollars in thousands)

	TEC, Prelim Design	Final Design	TEC, Construction	TEC, Total	OPC Except D&D	OPC, D&D	OPC, Total	TPC
FY 2012	5,326	9,998	33,226	43,224	14,413	N/A	14,413	62,963

4. Project Description, Justification, and Scope

The LANL PF-4 major facility and infrastructure systems are aging and approaching the end of their service life, and, as a consequence, are beginning to require excessive maintenance. As a result, the facility is experiencing increased operating costs and reduced system reliability. Compliance with safety and regulatory requirements is critical to mission essential operations, and thus becoming more costly and cumbersome to maintain due to the physical conditions of facility support systems and equipment.

This project will enhance safety and enable cost effective operations so that the facility can continue to support critical Defense Programs missions and activities. The LANL identified 20 subprojects at the pre-conceptual stage for upgrades and modernization. The subprojects were selected utilizing a risk-based prioritization process that considered the current condition of the equipment, risk of failure to the worker, the environment, and the public, and risk of failure to programmatic and facility operations.

During Conceptual Design, the project continued to refine the prioritization method and subprojects. Defense Program's Infrastructure Revitalization combined with impacts to available/anticipated funding has led to development of a phased acquisition strategy for the TRP project. To meet mission need objectives within the budgetary and strategic context constraints, the TRP project is proposed for execution as three separate, distinct capital line item projects, TRP Phase I, TRP Phase II, and TRP Phase III.

The project is being conducted in accordance with the project management requirements in DOE O 413.3B, Program and Project Management for the Acquisition of Capital Assets, and all appropriate project management requirements have been met.

Funds appropriated under this data sheet may be used to provide independent assessments of the planning and execution of this line item project.

TRP II Overall Scope: Consists of seven (7) subprojects to be completed in three phases:

1. Replace existing Uninterruptible Power Supply with nuclear grade equipment and relocate from the PF-4 to a new structure to allow simpler maintenance, proper exhaust, and to minimize mixed waste generation.
2. Refurbish three existing air dryers, demolition of the fourth, and provide a cross connect between the 300 and 400 area dryers so the 400 dryer can back up the 300 dryer within the PF-4. Modern controls will also be provided.
3. Replace six existing PF-4 confinement doors to allow the facility ventilation system to maintain pressure differential between the facility and the environment.
4. Replace existing Criticality Alarm detectors and circuits in the PF-4 with new and expandable detectors and electronics.
5. Upgrade two Pu-238 water storage tanks cooling system within the PF-4.
6. Seismically brace and qualify high priority (ignition source and high material at risk) glovebox stands in the PF-4 to meet safety requirements.
7. Upgrade the sampling system for the existing PF-4 exhaust stacks so that exhaust measuring equipment meets industry standards.

Phase A: Glovebox Stand 1 and Air Dryers:

Air Dryers – Refurbish three existing air dryers, demolition of the fourth, and provide a cross connect between the 300 and 400 area dryers so the 400 dryer can back up the 300 dryer within the PF-4. Modern controls will also be provided.

Glovebox Stands Group 1 – Seismically upgrade the stands for 10 high priority gloveboxes to ensure gloveboxes remain intact and do not topple during a seismic event.

Phase B: Glovebox Stand 2, Confinement Doors, and the demolition of PF-7 in support of the UPS:

Glovebox Stands Group 2 – Seismically upgrade the stands for 14 high priority gloveboxes ensure gloveboxes remain intact and do not topple during a seismic event.

Replace six existing PF-4 confinement doors to allow the facility ventilation system to maintain pressure differential between the facility and the environment.

Demolition of PF-7 – The demolition of PF-7 will provide space for the new structure to house the Uninterruptible Power Supply safety system.

Phase C: Glovebox Stand 3, Exhaust Stack, UPS, Criticality Alarm System, and Vault Water Tanks

Glovebox Stands Group 3 – Seismically upgrade the stands for the identified high priority gloveboxes to ensure gloveboxes remain intact and do not topple during a seismic event.

Upgrade the sampling system for existing PF-4 exhaust stacks so that exhaust measuring equipment meets industry standards.

Replace existing Uninterruptible Power Supply with nuclear grade equipment and relocate from the PF-4 to a new structure to allow simpler maintenance, proper exhaust, and to minimize mixed waste generation.

Upgrade two Pu-238 water storage tanks cooling system within the PF-4.

Replace existing Criticality Alarm detectors and circuits in the PF-4 with new and expandable detectors and electronics.

5. Financial Schedule

	(dollars in thousands)		
	Appropriations	Obligations	Costs
Total Estimated Cost (TEC)			
Design			
Preliminary Design (06-D-140-02)			
FY 2008	1,439[a]	1,439	24
FY 2009	8,245	8,245	3,403
FY 2010	5,000[b]	5,000	7,860
FY 2011	0	0	2,000
FY 2012	0	0	1,397
Total, Preliminary Design	14,684	14,684	14,684
Final Design (11-D-801)			
FY 2011	7,500	7,500	6,000
FY 2012	5,200	5,200	6,700
Total, Final Design	12,700	12,700	12,700
Total Design	27,384	27,384	27,384
Construction			
FY 2011	12,500	12,500	11,000
FY 2012	14,202	14,202	12,940
FY 2013	8,889	8,889	9,560
FY 2014	8,624	8,624	8,540
FY 2015	12,500	12,500	10,680
FY 2016	0	0	3,995
Total, Construction	56,715	56,715	56,715
TEC			
FY 2008	1,439	1,439	24
FY 2009	8,245	8,245	3,403
FY 2010	5,000	5,000	7,860
FY 2011	20,000	20,000	19,000
FY 2012	19,402	19,402	21,037
FY 2013	8,889	8,889	9,560
FY 2014	8,624	8,624	8,540
FY 2015	12,500	12,500	10,680
FY 2016	0	0	3,995
Total, TEC	84,099	84,099	84,099

[a] FY 2008 PED includes $360 that was transferred from TA-55 Reinvestment Project Phase I. Funding for both PED projects were appropriated under the same project line within Project 06-D-140.

[b] FY 2010 PED includes $1,000 that was transferred from 06-D-140-03, PED Radioactive Liquid Waste Treatment Facility Upgrade. Funding for both PED projects were appropriated under the same project data sheet.

	(dollars in thousands)		
	Appropriations	Obligations	Costs
Other Project Cost (OPC)			
OPC except D&D			
FY 2005	854	854	854
FY 2006	1,919	1,919	1,919
FY 2007	980	980	980
FY 2008	1,343	1,343	1,343
FY 2009	90	90	90
FY 2010	319	319	319
FY 2011	685	685	685
FY 2012	2,100	2,100	2,100
FY 2013	1,500	1,500	1,500
FY 2014	2,577	2,577	2,577
FY 2015	2,200	2,200	2,200
FY 2016	910	910	910
Total, OPC except D&D	15,477	15,477	15,477
D&D			
FY2010	NA	NA	NA
Total, D&D	NA	NA	NA
OPC			
FY 2005	854	854	854
FY 2006	1,919	1,919	1,919
FY 2007	980	980	980
FY 2008	1,343	1,343	1,343
FY 2009	90	90	90
FY 2010	319	319	319
FY 2011	685	685	685
FY 2012	2,100	2,100	2,100
FY 2013	1,500	1,500	1,500
FY 2014	2,577	2,577	2,577
FY 2015	2,200	2,200	2,200
FY 2016	910	910	910
Total, OPC	15,477	15,477	15,477
Total Project Cost (TPC)			
FY 2005	854	854	854
FY 2006	1,919	1,919	1,919
FY 2007	980	980	980
FY 2008	2,782	2,782	1,367
FY 2009	8,335	8,335	3,493
FY 2010	5,319	5,319	8,179
FY 2011	20,685	20,685	19,685
FY 2012	21,502	21,502	23,137
FY 2013	10,389	10,389	11,060
FY 2014	11,201	11,201	11,117
FY 2015	14,700	14,700	12,880
FY 2016	910	910	4,905
Total, TPC	99,576	99,576	99,576

6. Details of Project Cost Estimate

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design (PED)			
Preliminary Design (06-D-140)	12,619	11,619	TBD
Contingency	2,065	2,065	TBD
Final Design (11-D-801)	9,930	0	TBD
Final Design Contingency	2,770	0	TBD
Total, Design	27,384	13,684	TBD
Construction			
Site Preparation	TBD	TBD	TBD
Equipment	TBD	TBD	TBD
Other Construction	TBD	TBD	TBD
Contingency	TBD	TBD	TBD
Total, Construction	56,715	TBD	TBD
Total, TEC	84,099	TBD	TBD
Contingency, TEC	TBD	TBD	TBD
Other Project Cost (OPC)			
OPC except D&D			
Conceptual Planning	TBD	TBD	TBD
Conceptual Design	TBD	TBD	TBD
Start-Up	TBD	TBD	TBD
Contingency	TBD	TBD	TBD
Total, OPC except D&D	15,477	TBD	TBD
D&D			
D&D	N/A	N/A	TBD
Contingency	N/A	N/A	TBD
Total, D&D	N/A	N/A	TBD
Total, OPC	15,477	TBD	TBD
Contingency, OPC	TBD	TBD	TBD
Total, TPC	99,576	TBD	TBD
Total, Contingency	TBD	TBD	TBD

7. Schedule of Appropriation Requests

(dollars in thousands)

		Prior Years	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	Outyears	Total
FY 2011	TEC	13,684	20,000	19,640	20,221	20,468	42,480	TBD	TBD	TBD
	OPC	6,088	3,300	2,800	2,600	TBD	TBD	TBD	TBD	TBD
	TPC	19,772	23,300	22,440	22,821	20,468	42,480	TBD	TBD	TBD
FY 2012	TEC	14,684	20,000	19,402	8,889	8,624	12,500	0	0	84,099
	OPC	5,505	685	2,100	1,500	2,577	2,200	910	0	15,477
	TPC	20,189	20,685	21,502	10,389	11,201	14,700	910	0	99,576

8. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy (fiscal quarter or date)	TBD
Expected Useful Life (number of years)	25
Expected Future Start of D&D of this capital asset (fiscal quarter)	TBD

(Related Funding requirements)

(dollars in thousands)

	Annual Costs		Life Cycle Costs	
	Current Total Estimate	Previous Total Estimate	Current Total Estimate	Previous Total Estimate
Operations	N/A	N/A	N/A	N/A
Maintenance	N/A	N/A	N/A	N/A
Total, Operations & Maintenance	N/A	N/A	N/A	N/A

9. Required D&D Information

As the project is an investment in the infrastructure systems of an existing facility, construction and demolition activities are minimal and are directly related to replacement and upgrade of these systems.

Area	Square Feet
Area of new construction	1,200
Area of existing facility(s) being replaced	N/A
Area of additional D&D space to meet the “one-for-one” requirement	1,200

Name(s) and site location(s) of existing facility(s) to be replaced: Uninterruptible Power Supply is planned to be relocated immediately outside of the existing structure (this represents the 1,200 square feet).

10. Acquisition Approach

Design and Construction Management will be implemented by Los Alamos National Security, LLC through the LANL Management and Operating Contract. The TRP Acquisition Strategy is based on tailored procurement strategies for each subproject in order to mitigate risks. The TRP subprojects will be implemented via LANL-issued final design/construction contracts based on detailed performance requirements/specifications developed during the preliminary design phase.

Annex D

FY 2011 Biennial Plan and Budget Assessment on the Modernization and Refurbishment of the Nuclear Security Complex

May 2010

National Nuclear Security Administration
United States Department of Energy
1000 Independence Avenue, SW
Washington, D.C. 20585

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration fabrication capabilities require regular recapitalization to incorporate industry supported technology.

Future uranium storage capacity has been addressed through the recently completed Highly-Enriched Uranium Materials Facility (HEUMF). Plutonium storage capacities indicate a potential issue in the FY 2014 time frame. Plutonium storage capacities and options are being analyzed to develop a more holistic approach to resolving issues for the foreseeable future and provide better support for continued directed stockpile work activities.

There is also a need to clearly delineate between a baseline, or "potential" capacity and the actual number of units made. For example, Y-12 may have future baseline capacity of 80 canned subassemblies per year but the number actually produced in a given year could be far less depending on stockpile requirements. Thus, the capacities should be clearly understood as different from the number actually made in a given year. Historically, the number of actual units made is a fraction of the infrastructure capacity.

Capacities During NNSA Transitions

For most capabilities, transition from the infrastructure of today to a modernized infrastructure of tomorrow does not introduce rate-limiting concerns, because efficiencies are improving during the transition. Plutonium pit work is a concern because it is today's main rate-limiting capacity. The upgrades to PF-4 will address this capability and provide the required capability-based capacity. The new UPF is planned to be capability-based and the resulting capacity is expected to be lower than Y-12's existing old uranium production facilities. The existing Y-12 infrastructure was designed to support Cold-War stockpiles and thus it has a greater capacity than needed long-term, unless one of the existing facilities is unexpectedly shut down, resulting in a capacity of zero. Tables D–2 and D–3 show the transition of estimated plutonium and HEU capacities from today to 2024.

Table D–2.Transition Annual Plutonium Pit Capacities at Los Alamos National Laboratory (Bounding Estimates)

	Today	2016	2017	2018	2019	2020	2021	2022	2023	2024
Pits requiring most manufacturing process steps	10	10	15	20	20	40	60	80	80	80

Table D–3.Transition Annual HEU Canned Subassembly Capacities at Y-12

	Today	2016	2017	2018	2019	2020	2021	2022	2023	2024
CSAs requiring only reuse/ re-inspection (a) (b)	40	40	40	40	40	0-40	0-40	80	80	80
Refurbished or new CSAs	160	160	160	160	60-120	20-60	0-40	40-80	80	80

(a) Capacity over and above that assumed for refurbished or new CSAs; assumes UPF Program Requirements Document, Rev 4.

(b) A transition from existing facilities to UPF will occur in 2019 through 2021; the transition approach will be closely coupled to stockpile needs during that period.

	FY 2010 Actual Approp	FY 2011 Request	FY 2012 Request

(7) deploying applications for the NNSA Enterprise Secure Network as the common backbone for the Enterprise to exchange classified data, documents, drawings, and three-dimensional models (to maintain compatibility with existing weapons information systems and master nuclear schedules); and (8) execute feasibility studies in conjunction with the DoD (e.g., long-range standoff analysis of alternatives).

▪ **Plutonium Sustainment**	**141,909**	**190,318**	**154,231**

The Plutonium Sustainment program includes the technical skills, equipment and facilities to maintain the nation's plutonium manufacturing capability in support of the nuclear weapons stockpile. Additionally, the Plutonium Sustainment program supplements RTBF through a tax assessed based on the footprint utilized by the Plutonium Sustainment program in PF-4, as well as estimates of effluent and waste.

The FY 2012 mission scope includes: (1) support manufacturing modernization to include equipment and Industrial Engineering improvements to the manufacturing process; (2) maintain a base pit production capability; (3) support pre-production activities of a planned Defense Programs Power Supply mission. The Power Supply mission includes pre-production and facility improvements to support the assembly operation at Los Alamos National Laboratory. The base program capabilities include development to establish the capability to produce a second pit type, and development activities that include Los Alamos National Laboratory and Lawrence Livermore National Laboratory.

Total, Directed Stockpile Work	**1,564,290**	**1,898,379**	**1,963,583**

The Washington Post

Why New START deserves GOP support

By Henry A. Kissinger, George P. Shultz, James A. Baker III, Lawrence S. Eagleburger and Colin L. Powell
Thursday, December 2, 2010; A25

Republican presidents have long led the crucial fight to protect the United States against nuclear dangers. That is why Presidents Richard Nixon, Ronald Reagan and George H.W. Bush negotiated the SALT I, START I and START II agreements. It is why President George W. Bush negotiated the Moscow Treaty. All four recognized that reducing the number of nuclear arms in an open, verifiable manner would reduce the risk of nuclear catastrophe and increase the stability of America's relationship with the Soviet Union and, later, the Russian Federation. The world is safer today because of the decades-long effort to reduce its supply of nuclear weapons.

As a result, we urge the Senate to ratify the New START treaty signed by President Obama and Russian President Dmitry Medvedev. It is a modest and appropriate continuation of the START I treaty that expired almost a year ago. It reduces the number of nuclear weapons that each side deploys while enabling the United States to maintain a strong nuclear deterrent and preserving the flexibility to deploy those forces as we see fit. Along with our obligation to protect the homeland, the United States has responsibilities to allies around the world. The commander of our nuclear forces has testified that the 1,550 warheads allowed under this treaty are sufficient for all our missions - and seven former nuclear commanders agree. The defense secretary, the chairman of the Joint Chiefs of Staff and the head of the Missile Defense Agency - all originally appointed by a Republican president - argue that New START is essential for our national defense.

We do not make a recommendation about the exact timing of a Senate ratification vote. That is a matter for the administration and Senate leaders. The most important thing is to have bipartisan support for the treaty, as previous nuclear arms treaties did.

Although each of us had initial questions about New START, administration officials have provided reasonable answers. We believe there are compelling reasons Republicans should support ratification.

First, the agreement emphasizes verification, providing a valuable window into Russia's nuclear arsenal. Since the original START expired last December, Russia has not been required to provide notifications about changes in its strategic nuclear arsenal, and the United States has been unable to conduct on-site inspections. Each day, America's understanding of Russia's arsenal has been degraded, and resources have been diverted from national security tasks to try to fill the gaps. Our military planners increasingly lack the best possible insight into Russia's activity with its strategic nuclear arsenal, making it more difficult to carry out their nuclear deterrent mission.

Second, New START preserves our ability to deploy effective missile defenses. The testimonies of our military commanders and civilian leaders make clear that the treaty does not limit U.S. missile defense plans. Although the treaty prohibits the conversion of existing launchers for intercontinental and submarine-based ballistic missiles, our military leaders say they do not want to do that because it is more expensive and less effective than building new ones for defense purposes.

Finally, the Obama administration has agreed to provide for modernization of the infrastructure essential to maintaining our nuclear arsenal. Funding these efforts has become part of the negotiations in the ratification process. The administration has put forth a 10-year plan to spend $84 billion on the Energy Department's nuclear weapons complex. Much of the credit for getting the administration to add $14 billion to the originally proposed $70 billion for modernization goes to Sen. Jon Kyl, the Arizona Republican who has been vigilant in this effort. Implementing this modernization program in a timely fashion would be important in ensuring that our nuclear arsenal is maintained appropriately over the next decade and beyond.

Although the United States needs a strong and reliable nuclear force, the chief nuclear danger today comes not from Russia but from rogue states such as Iran and North Korea and the potential for nuclear material to fall into the hands of terrorists. Given those pressing dangers, some question why an arms control treaty with Russia matters. It matters because it is in both parties' interest that there be transparency and stability in their strategic nuclear relationship. It also matters because Russia's cooperation will be needed if we are to make progress in rolling back the Iranian and North Korean programs. Russian help will be needed to continue our work to secure "loose nukes" in Russia and elsewhere. And Russian assistance is needed to improve the situation in Afghanistan, a breeding ground for international terrorism.

Obviously, the United States does not sign arms control agreements just to make friends. Any treaty must be considered on its merits. But we have here an agreement that is clearly in our national interest, and we should consider the ramifications of not ratifying it.

Whenever New START is brought up for debate, we encourage all senators to focus on national security. There are plenty of opportunities to battle on domestic political issues linked to the future of the American economy. With our country facing the dual threats of unemployment and a growing federal debt bomb, we anticipate significant conflict between Democrats and Republicans. It is, however, in the national interest to ratify New START.

The writers were secretaries of state for the past five Republican presidents.

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The White House

Office of the Press Secretary

For Immediate Release
November 17, 2010

Fact Sheet: An Enduring Commitment to the U.S.

Nuclear Deterrent

President Obama has made an extraordinary commitment to ensure the modernization of our nuclear infrastructure, which had been neglected for years before he took office. Today, the Administration once again demonstrates that commitment with the release of its plans to invest more than $85 billion over the next decade to modernize the U.S. nuclear weapons complex that supports our deterrent. This represents a $4.1 billion increase over the next five years relative to the plan provided to Congress in May. This level of funding is unprecedented since the end of the Cold War.

In the five years preceding the start of this Administration, the National Nuclear Security Administration (NNSA) – charged with sustaining America's aging nuclear complex and stockpile – lost 20 percent of its purchasing power. As part of the 2010 Nuclear Posture Review, the Administration made a commitment to modernize our nuclear arsenal and the complex that supports it. To begin this effort, the President requested $7 billion for NNSA in fiscal year 2011 (FY 2011) – an increase of nearly 10 percent over the prior year.

Today's release of updated investment plans (in an update to the *'Section 1251 Report to Congress'*) shows this Administration's commitment to requesting the funding needed to sustain and modernize the nuclear complex. In particular, the Administration plans will:

- Add nearly $600 million in funding for FY 2012, resulting in a total planned FY 2012 budget request of $7.6 billion for NNSA weapons activities;
- Increase funding by $4.1 billion increase over the next five years relative to the plan provided to Congress in May – including an additional $340 million for the Uranium Processing Facility (Tennessee) and the Chemistry and Metallurgy Research Replacement (CMRR) facility (New Mexico); and
- Propose spending more than $85 billion for NNSA weapons activities over the next decade.

The above plans provide the best current estimate of costs for the nuclear weapons stockpile and infrastructure. As the UPF and CMRR facilities are only at the 45 percent design level, the Administration recognizes that the costs could change over time. At the present time, the range for the Total Project Cost for CMRR is $3.7 billion to $5.8 billion and the range for UPF is $4.2 billion to $6.5 billion. The Administration is committed to requesting the funds necessary to ensure completion of these facilities. The potential additional costs associated with these facilities are shown in the table below.

Planned Projections for Weapons Stockpile and Infrastructure Spending
(*then-year dollars in billions*)

Fiscal Year

FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020
6.4	7.0	7.6	7.9	8.4	8.7	8.9	8.9 – 9.0	9.2 – 9.3	9.4– 9.6	9.4– 9.8

Blog posts on this issue

- April 22, 2011 6:28 PM EDT

  ### A Statement by President Obama on Syria

  President Obama releases a statement on Syria, "condemn[ing] in the strongest possible terms the use of force by the Syrian government against demonstrators."

November 2010 Update to the National Defense Authorization Act of FY2010
Section 1251 Report
New START Treaty Framework and Nuclear Force Structure Plans

1. Introduction

This paper updates elements of the report that was submitted to Congress on May 13, 2010, pursuant to section 1251 of the National Defense Authorization Act for Fiscal Year 2010 (Public Law 111-84) ("1251 Report").

2. National Nuclear Security Administration and modernization of the complex – an overview

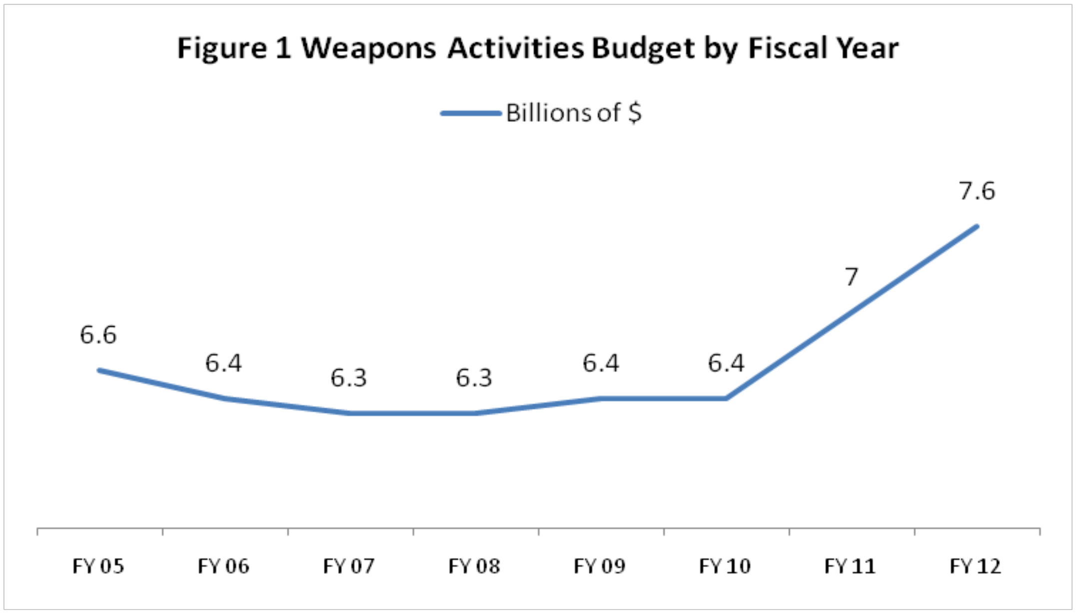
From FY 2005 to FY 2010, a downward trend in the budget for Weapons Activities at the National Nuclear Security Administration (NNSA) resulted in a loss of purchasing power of approximately 20 percent. As part of the 2010 Nuclear Posture Review, the Administration made a commitment to modernize America's nuclear arsenal and the complex that sustains it, and to continue to recruit and retain the best men and women to maintain our deterrent for as long as nuclear weapons exist. To begin this effort, the President requested a nearly 10 percent increase for Weapons Activities in the FY 2011 budget, and $4.4 billion in additional funds for these activities for the FY 2011 Future Years Nuclear Security Plan (FYNSP).[1] These increases were reflected in the 1251 report provided to Congress in May 2010.

The Administration spelled out its vision of modernization through the course of 2010. In February, soon after the release of the President's budget, the Vice President gave a major address at the National Defense University in which he highlighted the need to invest in our nuclear work force and facilities. Several reports to Congress provided the details of this plan, including: NNSA's detailed FY 2011 budget request, submitted in February; the strategy details in the *Nuclear Posture Review* (NPR) (April); the 1251 report (May); and the multi-volume *Stockpile Stewardship and Management Plan (SSMP)* (June). Over the last several months, senior Administration officials have testified before multiple congressional committees on the modernization effort.

The projections in the Future Years Nuclear Security Plan (FYNSP) that accompanied the FY 2011 budget submission and the 1251 report by the President are, appropriately called, 'projections.' They are not a 'fixed in stone' judgment of how much a given project or program may cost. They are a snapshot in time of what we expect inflation and other factors to add up to, given a specific set of requirements (that are themselves not fixed) over a period of several years. Budget projections, whether in the FYNSP and other reports, are evaluated each year and adjusted as necessary.

[1] After adjustment for the transfer of the Pit Disassembly and Conversion Facility from the Weapons Activities account to the Defense Nuclear Nonproliferation Account the increase over the FYNSP is actually $5.4 billion.

Indeed, planning and design, as well as budget estimates, have evolved since the budget for FY 2011 was developed. Notably, stockpile requirements to fully implement the NPR and the New START Treaty have been refined, and the NNSA has begun executing its *Stockpile Stewardship and Management Plan* (SSMP). This update will discuss, in particular, evolving life extension programs (LEP) and progress on the designs of key facilities such as the Uranium Processing Facility (UPF) and the Chemistry and Metallurgy Research Replacement (CMRR).



Note: FY 2011 level is the President's budget request; FY 2012 is the planned request.

Based on this additional work, and the development of new information and insights, the President is prepared to seek additional resources for the Weapons Activities account, over and above the FY 2011 FYNSP, for the FY 2012 budget and for the remainder of the FYNSP period (FY 2013 through FY 2016).

Specifically, the President plans to request $7.6 billion for FY 2012 (an increase of $0.6 billion over the planned FY 2012 funding level included in the FY 2011 FYNSP). Thus, in two years, the level of funding for this program requested will have increased by $1.2 billion, in nominal terms, over the $6.4 billion level appropriated in FY 2010. Altogether, the President plans to request $41.6 billion for FY 2012-2016 (an increase of $4.1 billion over the same period from the FY 2011 FYNSP[2]).

Given the extremely tight budget environment facing the federal government, these requests to the Congress demonstrate the priority the Administration's places on maintaining the safety, security and effectiveness of the deterrent.

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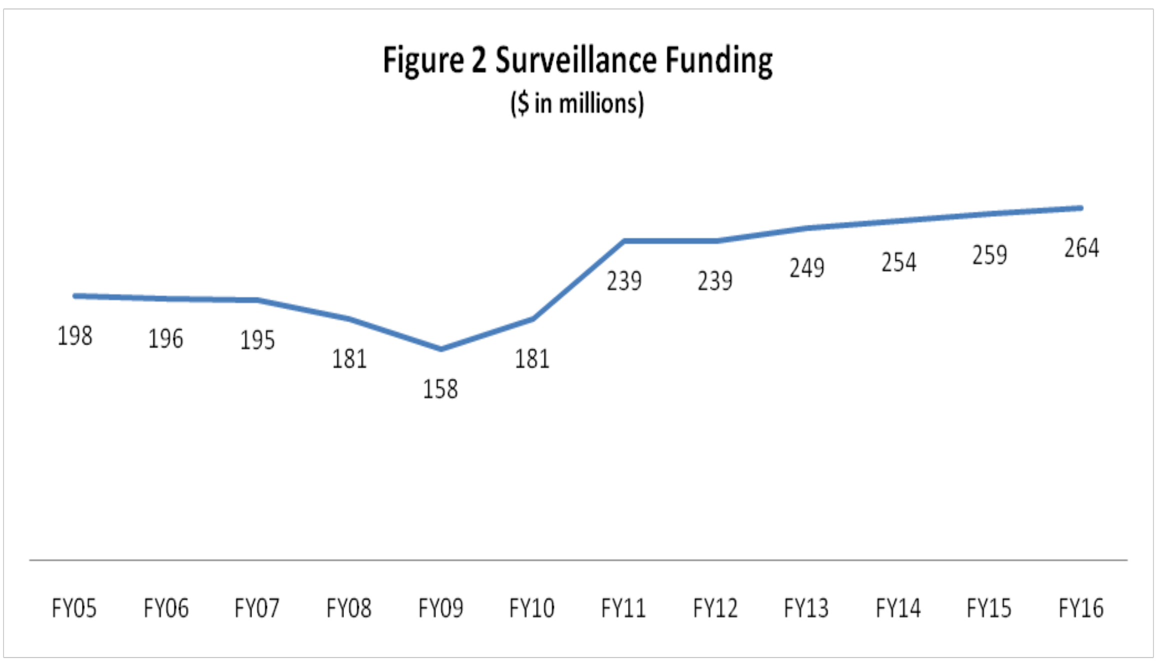
[2] As extended in the 1251 Report

3. NNSA -- Program Changes and New Requirements since submission of the *1251 Report*

A. Update to Stockpile Stewardship and Sustainment

Surveillance – Surveillance activities are essential to enabling continued certification of the reliability of the stockpile without nuclear testing. Surveillance involves withdrawing weapons from deployment and subjecting them to laboratory tests, as well as joint flight tests with the DoD to assess their reliability. These activities allow detection of possible manufacturing and design defects as well as material degradation over time. NNSA has also received recommendations from the National Laboratory directors, the DoD, the STRATCOM Strategic Advisory Group, and the JASON Defense Advisory Panel that the nuclear warhead/bomb surveillance program should be expanded.

In response to this broad-based advice, NNSA has reviewed the stockpile surveillance program and its funding profile. From FY 2005 through FY 2009, funding for surveillance activities, when adjusted for inflation, fell by 27 percent. In recognition of the serious concerns raised by chronic underfunding of these activities, beginning in FY 2010, the surveillance budget has been increased by 50 percent, from $158 million to $239 million. In the FY 2012 budget, the President will seek to sustain this increase throughout the FYNSP. This level of funding will assure that the required surveillance activities can be fully sustained over time.



Weapon System Life Extension -- The Administration is committed to pursuing a fully funded Life Extension Program for the nuclear weapons stockpile. The FY 2011 budget submission and the NPR outlined initial plans. Since May 2010, additional work has further defined the requirements to extend the life of the following weapon systems:

- **W76 –** The Department of Defense has finalized its assessment of the number of W76 warheads recommended to remain in the stockpile to carry out current guidance. The number of W76-1 life-extended warheads needing completion is larger than NNSA built into its FY 2011 budget plans. NNSA, with the support of the DoD, has adjusted its plan accordingly to ensure the W76-1 build is completed in FY 2018, an adjustment of one year that is endorsed by the Nuclear Weapons Council. This adjustment will not affect the timelines for B61 or W78 life extensions. The LEP will be fully funded for the life of the program at $255 million annually.

- **B61 –** NNSA began the study on the nuclear portion of the B61 life extension in August 2010, six months later than the original planning basis. To overcome this delay, NNSA will accelerate the technology maturation, warhead development, and production engineering that is necessary to retain the schedule for the completion of the first production unit in FY 2017. An additional $10 million per year has been added to the FY 2012 FYNSP for this purpose.

- **W88 AF&F –** The *1251 Report* addressed the intent to study, among other things, a common warhead for the W78 and the W88 as an option for W78 life extension. Early development of a W88 Arming, Fuzing, and Firing system (AF&F) would enhance the evaluation of commonality options and enable more efficient long-term sustainment of the W88. Approximately $400 million has been added to the FY 2012-16 FYNSP for this purpose.

- **Stockpile Systems and Services –**NNSA is now seeking to execute a larger program of stockpile maintenance than assumed in planning the FY 2011 budget and than projected in the *1251 Report*. The additional work includes an increase in the development/production of the limited life components to support the weapons systems. Consequently, the Administration plans to request increased funding of $40 million in FY 2012 for the production of neutron generators and gas transfer systems. NNSA and DoD are aligned for the delivery of essential hardware to ensure no weapon fails to meet requirements.

New Experiments — NNSA's current science and surveillance activities have been more successful than originally anticipated in ensuring the reliability of our existing stockpile without nuclear testing. As we continue to develop modern life extension programs, however, NNSA and the laboratories are considering even more advanced methods for evaluating the best technical options for life extension programs, including refurbishment, reuse and replacement of nuclear components. One such effort of interest that could aid in our efforts includes expanded subcritical experiments designed to modernize warhead safety and security features without adding new military capabilities or pursuing explosive nuclear weapons testing. This program might include so-called "scaled experiments" that could improve the performance of predictive capability calculations by providing data on plutonium behavior under compression by insensitive high explosives. In order to thoroughly understand this issue, to assess its cost-effectiveness and to ensure that there is a sound technical basis for any such effort, the Administration will conduct a review of these proposed activities and potential alternatives.

B. Updates to Modernization of the Nuclear Weapons Complex – Modernization of the complex includes reducing deferred maintenance, constructing replacement facilities, and disposing of surplus facilities. The Administration is committed to fully fund the construction of the Uranium Processing Facility (UPF) and the Chemistry and Metallurgy Research Replacement (CMRR), and to doing so in a manner that does not redirect funding from the core mission of managing the stockpile and sustaining the science, technology and engineering foundation. To this end, in addition to increased funding for CMRR and UPF, the FY 2012 budget will increase funding over the FY 2012 number in the 2011 FYNSP for facilities operations and maintenance by approximately $176 million.

Readiness in Technical Base and Facilities (RTBF): CMRR and UPF Construction – These two nuclear facilities are required to ensure the United States can maintain a safe, secure and effective arsenal over the long-term. The NPR concluded that the United States needed to build these facilities; the Administration remains committed to their construction.

Construction of large, one-of-a-kind facilities such as these presents significant challenges. Several reviews by the Government Accountability Office, as well as a "root-cause" analysis conducted by the Department of Energy in 2008, have found that initiating construction before designs are largely complete contributes to increased costs and schedule delays. In response to these reviews, and in order to assure the best value for the taxpayers, NNSA has concluded that reaching the 90% engineering design stage before establishing a project baseline for these facilities is critical to the successful pursuit of these capabilities.

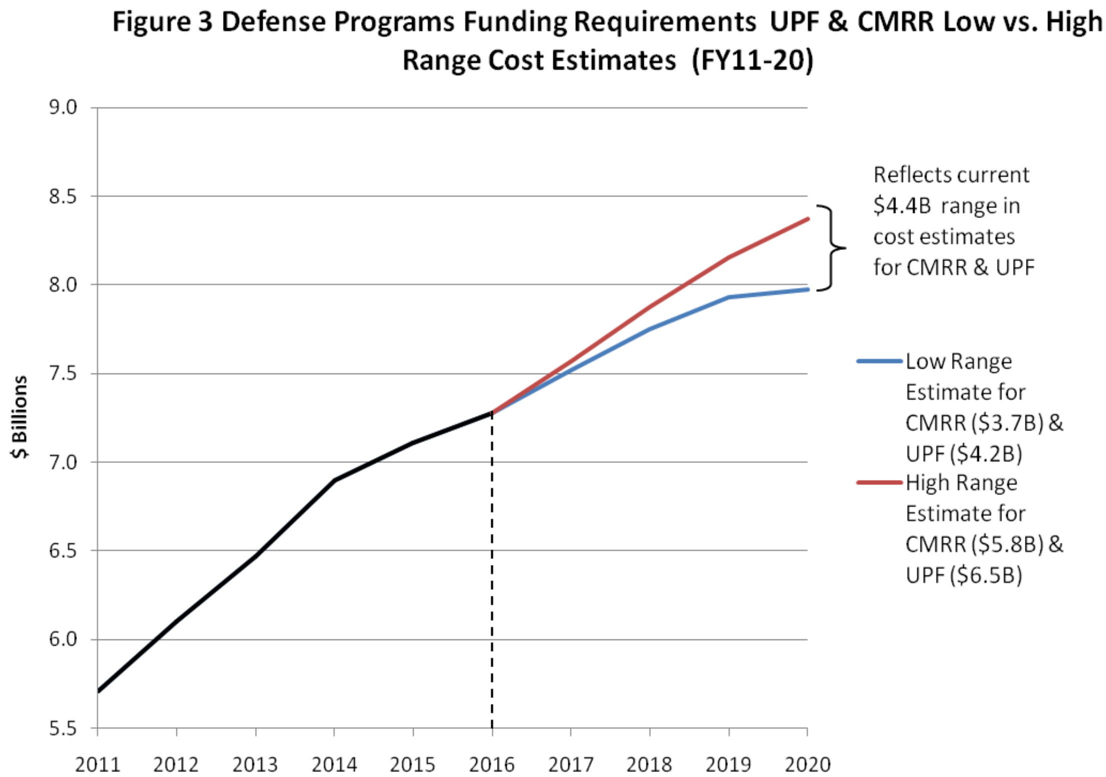
The ten-year funding plan reported in the *1251 Report* reflected cost estimates for these two facilities that were undertaken at a very early stage of design (about 10% complete), were preliminary, and could not therefore provide the basis for valid, longer-range cost estimates. The designs of these two facilities are now about 45% completed; the estimated costs of the facilities have escalated. Responsible stewardship of the taxpayer dollars required to fund these facilities requires close examination of requirements of all types and to understand their associated costs, so that NNSA and DoD can make informed decisions about these facilities. To this end, NNSA, in cooperation with the DoD, is carrying out a comprehensive review of the safety, security, environmental and programmatic requirements that drive the costs of these facilities. In parallel with, and in support of this effort, separate independent reviews are being conducted by the Corps of Engineers and the DOE Chief Financial Officer's Cost Analysis Office. In addition, the

Secretary of Energy is convening his own review, with support from an independent group of senior experts, to evaluate facility requirements.

The overriding focus of this work is to ensure that UPF and CMRR are built to achieve needed capabilities without incurring cost overruns or scheduling delays. We expect that construction project cost baselines for each project will be established in FY 2013 after 90% of the design work is completed. At the present time, the range for the Total Project Cost (TPC) for CMRR is $3.7 billion to $5.8 billion and the TPC range for UPF is $4.2 billion to $6.5 billion. TPC estimates include Project Engineering and Design, Construction, and Other Project Costs from inception through completion. Over the FYNSP period (FY 2012-2016) the Administration will increase funding by $340 million compared with the amount projected in the FY 2011 FYNSP for the two facilities.

At this early stage in the process of estimating costs, it would not be prudent to assume we know all of the annual funding requirements over the lives of the projects. Funding requirements will be reconsidered on an ongoing basis as the designs mature and as more information is known about costs. While innovative funding mechanisms, such as forward funding, may be useful in the future for providing funding stability to these projects, at this early design stage, well before we have a more complete understanding of costs, NNSA has determined that it would not yet be appropriate and possibly counterproductive to pursue such a mechanisms until we reach the 90% design point. As planning for these projects proceeds, NNSA and OMB will continue to review all appropriate options to achieve savings and efficiencies in the construction of these facilities.

The combined difference between the low and high estimates for the UPF and CMRR facilities ($4.4 billion) results in a range of costs beyond FY 2016 as shown in Figure 3. Note that for the high estimate, the facilities would reach completion in FY 2023 for CMRR and FY 2024 for UPF. For each facility, functionality would be attainable by FY 2020 even though completion of the total projects would take longer.



* Anticipated costs for contractor pensions have been calculated only through FY 2016. For FY 2017-2020, uncertainties in market performance, interest rate movement, and portfolio management make prediction of actual additional pension liabilities, assets, and contribution requirements unreliable.

Readiness in the Technical Base of Facilities (RTBF) - Operations and Maintenance
In order to implement an increased scope of work for stockpile activities, especially surveillance and the ongoing life extension programs (LEPs), the following will be supported:

- **NNSS –** Full experimental facility availability to support ongoing subcritical and other experiments necessary for certification of life extension technologies.
- **Pantex –** Funds are included in the FY 2012 request to fully cover anticipated needs for flood prevention.
- **SNL –** Replacement of aging and failing equipment at the Tonopah Test Range in Nevada to facilitate the increasing pace of operations support for the B61; and Micro-electronics, engineering test, and surveillance actions at SNL to support the B61, W76 and W78 that require additional equipment maintenance in facilities and the need to operate engineering test facilities that currently operate in a periodic campaign mode.
- **LLNL**, **LANL**, and **Y-12 –** Investments in infrastructure and construction, including support for Site 300, PF-4, and Nuclear Facilities Risk Reduction.

- **Kansas City –** Investment sufficient to meet LEP needs for the W76-1, B-61, and W78/88 while preparing and completing the move to the KCRIMS site at Botts Road.
- **Savannah River –** Sufficient investment to ensure that availability of tritium supplies adequate for stockpile needs is assured.

RTBF: Other Construction – As the CMRR and UPF projects are completed, NNSA will continue to modernize and refurbish the balance of its physical infrastructure over the next ten years. The FY 2012 budget request includes $67 million for the High Explosive Pressing Facility project that is ongoing at Pantex, $35 million for the Nuclear Facilities Risk Reduction Project at Y-12, $25 million for the Test Capabilities Revitalization Project at Sandia, as well as $9.8 million for the Transuranic Waste Facility and $20 million for the TA-55 Reinvestment Project at LANL.

RTBF: Construction Management – Because of the unprecedented scale of construction that NNSA is initiating, both in the nuclear weapons complex and in non-proliferation activities, the Administration recognizes that stronger management structures and oversight processes will be needed to prevent cost growth and schedule slippage. NNSA will work with DoD, OMB, and other affected parties to analyze current processes and to consider options for enhancements.

C. Pension Cost Growth and Alternative Mitigation Strategies

NNSA has a large contractor workforce that is covered by defined-benefit pension plans for which the U.S. Government assumes liability. Portfolio management decisions, market downturns, interest rate decreases, and new statutory requirements have caused large increases in pension costs. The Administration is fully committed to keeping these programs solvent without harming the base programs. The Administration will therefore cover total pension reimbursements of $875 million for all of NNSA for FY 2012, adding $300 million more to the NNSA topline than the amount provided in FY 2011. Over the five year period FY 2012 to FY 2016, the Administration will provide a total of $1.5 billion above the FY 2011 level. About three-quarters of this funding is associated with Weapons Activities and is included in the funding totals for those programs noted above.

The Administration will conduct an independent study of these issues using the appropriate statutory and regulatory framework to inform longer-term decisions on pension reimbursements. The Administration is evaluating multiple approaches to determine the best path to cover pension plan contributions, while minimizing the impact to mission. Contractors are evaluating mitigation strategies, such as analyzing plan changes, identifying alternative funding strategies, and seeking increased participant contributions. Also, contractors have been directed to look into other human resource areas where savings can be achieved, in order to help fund pension plan contributions.

3. Summary of NNSA Stockpile and Infrastructure Costs

A summary of estimated costs specifically related to the Nuclear Weapons Stockpile, the supporting infrastructure, and critical science, technology and engineering is provided in Table 1.

Table 1 Ten Year Projections for Weapons Stockpile and Infrastructure Costs

	Fiscal Year										
$ Billions	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Directed Stockpile	1.5	1.9	2.0	2.1	2.3	2.5	2.6	2.6	2.6	2.6	2.6
Science Technology & Engineering Campaigns	1.6	1.7	1.8	1.8	1.8	1.8	1.9	2.0	2.1	2.2	2.3
Readiness in Technical Base and Facilities	1.8	1.8	2.1	2.3	2.5	2.5	2.5	2.7	2.8-2.9	2.9-3.1	2.9-3.3
UPF	*0.1*	*0.1*	*0.2*	*0.2*	*0.4*	*0.4*	*0.4*	*0.48-0.5*	*0.48-0.5*	*0.48-0.5*	*0.38-0.5*
CMRR	*0.1*	*0.2*	*0.3*	*0.3*	*0.4*	*0.4*	*0.4*	*0.48-0.5*	*0.4-0.5*	*0.3-0.5*	*0.2-0.5*
Secure Transportation	0.2	0.2	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Defense Programs Subtotal	**5.2**	**5.7**	**6.1**	**6.5**	**6.9**	**7.1**	**7.3**	**7.5-7.6**	**7.7-7.9**	**7.9-8.2**	**8.0-8.4**
Other Weapons	1.2	1.3	1.3	1.3	1.3	1.3	1.4	1.4	1.4	1.4	1.5
Subtotal, Weapons	**6.4**	**7.0**	**7.4**	**7.8**	**8.2**	**8.5**	**8.7**	**8.9-9.0**	**9.2-9.3**	**9.4-9.6**	**9.4-9.8**
Contractor Pensions Cost Growth			0.2	0.2	0.2	0.2	0.2	* TBD	* TBD	* TBD	* TBD
Total, Weapons	**6.4**	**7.0**	**7.6**	**7.9**	**8.4**	**8.7**	**8.9**	**8.9-9.0**	**9.2-9.3**	**9.4-9.6**	**9.4-9.8**

Numbers may not add due to rounding

* Anticipated costs for contractor pensions have been calculated only through FY 2016. For FY 2017-2020, uncertainties in market performance, interest rate movement, and portfolio management make prediction of actual additional pension liabilities, assets, and contribution requirements unreliable.

4. Plans for Sustaining and Modernizing U.S. Strategic Delivery Systems

The Administration remains committed to the sustainment and modernization of U.S. strategic delivery systems, to ensure continuing deterrent capabilities in the face of evolving challenges and technological developments. DoD's estimates of costs to sustain and modernize strategic delivery systems will be updated as part of the President's FY 2012 budget request; until this budget request is finalized, figures provided in the May 2010 *1251 report* remain the best available cost estimates.

The following section of this report provides the latest information on DoD's efforts to modernize the Triad, including expected timelines for key decisions.

Strategic Submarines (SSBNs) and Submarine-Launched Ballistic Missiles (SLBMs)

As the *NPR* and the *1251 Report* note, the United States will maintain continuous at-sea deployments of SSBNs in the Atlantic and Pacific Oceans, as well as the ability to surge additional submarines in crisis. The current Ohio-class SSBNs, have had their service life extended by a decade and will commence retirement in FY 2027. DoD plans a transition between the retiring Ohio-class SSBNs and the Ohio-class replacement that creates no gap in the U.S. sea-based strategic deterrent capability.

Current key milestones for the SSBN replacement program include:

- Research, development, test, and evaluation (RDT&E) began in FY 2010 and continues with the goal of achieving 10 percent greater design maturity prior to starting procurement than the USS VIRGINIA class had before procurement started;
- In FY 2015, the Navy will begin the detailed design and advanced procurement of critical components;
- In FY 2019, the Navy will begin the seven-year construction period for the new SSBN lead ship;
- In FY 2026, the Navy will begin the three-year strategic certification period for the lead ship; and
- In FY 2029, the lead ship will commence active strategic at-sea service.

The Analysis of Alternatives (AoA) considered three platforms concepts for the Ohio-class Replacement: VIRGINIA-Insert, OHIO-Like, and a New Design. DoD is currently evaluating the advantages and disadvantages of each concept, including cost tradeoffs, with the goal of meeting military requirements at an affordable cost. An initial milestone decision is expected by the end of calendar year 2010 to inform the program and budget moving forward.

After the initial milestone design decision is made, DoD will be able to provide any adjustments to the estimated total costs for the Ohio-class replacement program. Thus, today's estimated total costs for FY 2011 through FY 2020 remain the same as reported in the *1251 Report*: a total of approximately $29.4 billion with $11.6 billion for R&D and $17.8 billion for design and procurement.

As noted in the *1251 Report*, the Navy plans to sustain the Trident II D5 missile, as carried on Ohio-class Fleet SSBNs as well as the next generation SSBN, through a least 2042 with a robust life-extension program.

Intercontinental Ballistic Missiles (ICBMs)

As stated in the Nuclear Posture Review, while a decision on an ICBM follow-on is not needed for several years, preparatory analysis is needed and is in fact now underway. This work will consider a range of deployment options, with the objective of defining a cost-effective approach for an ICBM follow-on that supports continued reductions in U.S. nuclear weapons while promoting stable deterrence. Key milestones include:

- The Capabilities-Based Assessment (CBA) for the ICBM follow-on system is underway.
- By late 2011, the study plan for the AoA, including the scope of options to be considered, will be completed.
- In 2012, the AoA will begin.
- In FY 2014, the AoA will be completed, and DoD will recommend a specific way-ahead for an ICBM follow-on to the President.

The Air Force is funding the ongoing CBA effort at approximately $26 million per year. Given the inherent uncertainties about missile configuration and basing prior to the completion of the AoA, DoD is unable to provide costs for its potential development and procurement at this time. However, DoD expects to be able to include funding for RDT&E for an ICBM follow-on system in the FY 2013 budget request, based on initial results from the AoA.

The Air Force plans to sustain the Minuteman III through 2030. That sustainment includes substantial ongoing life extension programs, cost data for which was provided to Congress in the May 2010 Section 1251 Report.

Heavy Bombers

DoD plans to sustain a heavy bomber leg of the strategic Triad for the indefinite future, and is committed to the modernization of the heavy bomber force. Thus, the question being addressed in DoD's ongoing long-range strike study is not whether to pursue a follow-on heavy bomber, but the appropriate type of bomber and the timelines for development, production, and deployment. The long-range strike study, which is also considering related investments in electronic attack, intelligence, surveillance and reconnaissance, air- and sea-delivered cruise missiles, and prompt global strike, will be completed in time to inform the President's budget submission for FY 2012.

As stated in the May 2010 1251 Report, pending the results of the long-range strike study, estimated costs for a follow-on bomber for FY 2011 through FY 2015 are $1.7 billion and estimated costs beyond FY 2015 are to-be-determined. DoD intends to provide any necessary updates to cost estimates along with the President's budget submission for FY 2012.

The Air Force plans to retain the B-52 in the inventory through at least 2035 to continue to meet both nuclear and conventional mission requirements. The Air Force will make planned upgrades and life extensions to the fleet. The B-2 fleet is being upgraded through three top priority acquisition programs: the Radar Modernization Program (RMP), Extremely High Frequency (EHF) Satellite Communications and Computers, and Defensive Management System (DMS), as well as multiple smaller sustainment initiatives.

Air Launched Cruise Missile (ALCM)

DoD intends to replace the current ALCM with the advanced long range standoff (LRSO) cruise missile. The CBA for the LRSO is underway. An AoA will be conducted from approximately spring 2011 through fall 2013. The AoA will define the platform requirements, provide cost-sensitive comparisons, validate threats, and establish measures of effectiveness, and assess candidate systems for eventual procurement and production.

The Air Force has programmed approximately $800 million for RDT&E over the FYDP for the development of LRSO. Based on current analysis of the program, the Air Force expects low rate initial production of LRSO to being in approximately 2025, while the current ALCM will be sustained through 2030. Until the planned AoA is completed, DoD will not have a basis for accurately estimating subsequent costs.