# Making Smart Security Choices

## The Future of the U.S. Nuclear Weapons Complex

Union of Concerned Scientists

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Lisbeth Gronlund

Eryn MacDonald

Stephen Young

Philip E. Coyle III

Steve Fetter

Union of Concerned Scientists

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**Lisbeth Gronlund** is a senior scientist and co-director of the Union of Concerned Scientists (UCS) Global Security Program.

**Eryn MacDonald** is an analyst in the UCS Global Security Program.

**Stephen Young** is a senior analyst in the UCS Global Security Program.

**Philip E. Coyle III** is a senior science fellow at the Center for Arms Control and Non-Proliferation.

**Steve Fetter** is a professor in the School of Public Policy at the University of Maryland.

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*Four B61 nuclear gravity bombs on a bomb cart at Barksdale Air Force Base in Louisiana.*

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# Executive Summary

The mission of the U.S. nuclear weapons complex is to ensure a safe, secure, and reliable nuclear arsenal. The complex must be able to extend the life of nuclear warheads, assess their reliability and safety, understand the impact of aging and modifications, and retain employees with essential scientific and technical expertise. Just as important for U.S. security, the complex should dismantle retired weapons in a timely fashion, and develop methods for verifying further reductions in nuclear weapons. The complex must also minimize the security risks entailed in storing, transporting, and disposing of weapons-usable materials.

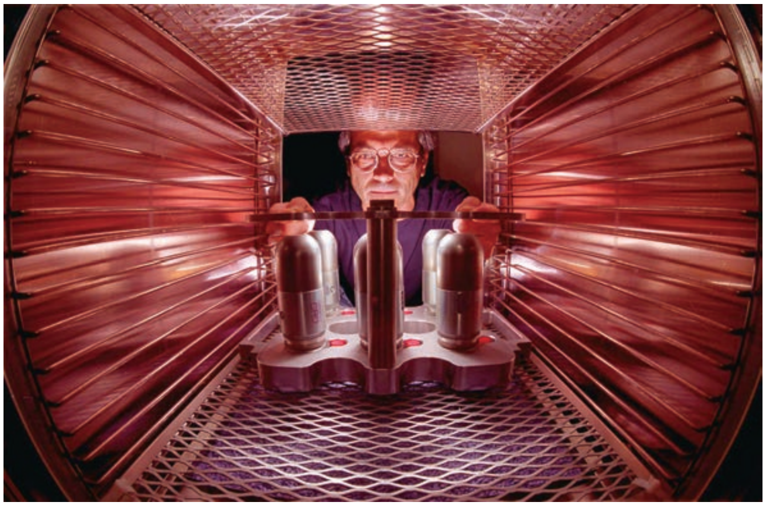
The complex must meet all these challenges with limited resources. Doing so will require making smart choices based on strict attention to priorities.

The administration and Congress will make key decisions on the nuclear weapons complex over the next few years. Toward that end, this report examines the essential missions of the complex, considers its key challenges, and suggests critical near-term and long-term steps.

## Extending the Life of Nuclear Weapons

The National Nuclear Security Administration (NNSA)—the semi-autonomous agency within the Department of Energy that oversees U.S. nuclear weapons activities—plans to replace the seven types of weapons in today's arsenal with five different weapons over the next 25 to 30 years. The NNSA is planning to construct new facilities to produce canned subassemblies and high explosive, and to allow an increase in the production of plutonium pits. It is also planning to increase the amount of tritium in U.S. weapons, to allow less frequent maintenance and increase weapon reliability.

- The NNSA should give strong preference to refurbishing or remanufacturing existing weapon types. Creating new weapon types—even if they only use weapon components of existing designs—would be viewed by many as violating the administration's pledge not to develop or deploy new nuclear weapons, and could generate concerns about weapon reliability.


An employee slides a tray of W76 neutron generator tubes into a desiccator (drying) cabinet at the Explosive Components Facility at Sandia National Laboratory.

- Assuming the United States makes modest reductions in its nuclear arsenal over the next 25 years, existing facilities can produce enough plutonium pits to sustain the arsenal, even when some life extension programs entail building new pits. The Chemistry and Metallurgy Research Replacement–Nuclear Facility at Los Alamos National Laboratory, currently on hold, is not needed. The administration should cancel it, and develop a plan to minimize the number of sites that store and handle plutonium.
- The planned Uranium Processing Facility at the Y-12 National Security Complex in Tennessee may have more capacity than needed to produce new canned subassemblies. That need depends on the ability to refurbish existing secondaries and other components, and on whether future life extension programs will entail newly produced components. A careful examination of the need for new canned subassemblies is in order. The United States should delay construction of the facility until the production capacity required to support the stockpile is clearer.
- The NNSA should defer building a second press in the High Explosives Pressing Facility at the

Photo: Randy Montoya/Sandia National Laboratory

Pantex Plant in Texas until the agency demonstrates a need for it.

- The nation has a robust capacity to produce tritium. Existing facilities can supply the needed amount.
- The NNSA should reevaluate the requirement for a five-year tritium reserve, given that commercial reactors are producing tritium and that production can expand more quickly than in the past.
- To provide any fuel needed for tritium-producing reactors, the NNSA should down-blend some of its large existing stockpiles of highly enriched uranium (HEU) to low-enriched uranium (LEU).
- Congress should not subsidize USEC—the domestic uranium enrichment company—or its American Centrifuge Plant to produce LEU to fuel tritium-producing commercial reactors.

## Ensuring Robust Surveillance

Under its Stockpile Surveillance Program, the NNSA removes some of each type of warhead from the stockpile each year, and subjects them to a wide variety of non-nuclear tests to assess their reliability, safety, and security. The NNSA has not made this program a priority, creating concern about the agency's ability to continue to certify the reliability, safety, and security of the U.S. nuclear arsenal.

- The NNSA and Congress should devote the attention and funding needed to ensure a robust surveillance program, even in the face of budget constraints.
- Congress should monitor the NNSA's progress in developing and implementing its corrective action plan for the surveillance program, and in completing baseline tests for key components of nuclear weapons.
- Both Congress and the NNSA should give serious consideration to recommendations from a forthcoming study of the surveillance program by the JASON scientific advisory group.

## "Rightsizing" Stockpile Stewardship

The Stockpile Stewardship Program helps develop a more in-depth understanding of how nuclear weapons work. But such understanding should not be an end in itself. Instead, this program's facilities and experiments should align with the priorities and needs of life extension programs for existing nuclear weapons, which will depend on the extent to which life extension programs entail aggressive modifications or replacement weapons with newly designed nuclear components. Not only will more aggressive life extension programs be more expensive to implement, they will also require greater computing and experimental resources. A complete accounting of the financial costs of different life extension programs should include the associated stockpile stewardship costs as well.

- The NNSA has three facilities where scientists conduct hydrodynamic tests. The NNSA and Congress should assess the need to continue using the Big Explosive Experimental Facility for such tests.
- The NNSA and Congress should also assess the need to build the Large Bore Powder Gun for shock wave tests, given that two similar facilities are already operating.
- The administration or Congress should ask the JASON group to assess the utility of the hydrodynamic and shock-wave facilities for stockpile certification, under various assumptions regarding changes made to weapons during life extension programs.
- The NNSA has three facilities that are used to conduct nuclear fusion experiments and to study materials under conditions of high energy: the National Ignition Facility, the Z machine, and OMEGA. The administration or Congress should ask the JASON group to assess the utility of these three facilities to the Stockpile Stewardship Program. The study should consider the extent to which the facilities provide unique information relevant to stockpile certification, and the value of such information for stockpile certification under different assumptions about changes made to weapons during life extension programs.
- The administration or Congress should ask the JASON group to assess the computing capacity needed to support the stockpile, under different assumptions about modifications made to weapons during life extension programs.

## Retaining a Qualified Workforce

A highly skilled scientific and technical workforce is essential to the NNSA's ability to maintain the stockpile. The nuclear weapons complex will continue to compete with other industries to attract qualified employees, and security requirements may make jobs at the complex less attractive for younger workers than employment in private industry.

- The NNSA has been able to attract and retain people with the needed expertise. No major change in strategy is needed. The agency and its contractors should continue to offer competitive salaries and benefits.
- Programs such as Work for Others, the Livermore Valley Open Campus, and Directed Research and Development allow technical workers to perform

research for other federal and nongovernmental sponsors, and to connect with the broader scientific community. The NNSA should expand these programs and encourage new ones.

- The NNSA should ensure that its contractors make full use of funding for the Directed Research and Development programs, which support basic research.
- The NNSA and its contractors should provide working conditions with fewer bureaucratic constraints.

### Minimizing the Risks of Storing and Disposing of Weapons-Grade Material

The United States has large amounts of plutonium and HEU that are not needed for military purposes. A key mission of the nuclear complex is to safely and securely store and dispose of these fissile materials, which can be used directly to make nuclear weapons, in order to prevent their theft or diversion.

- The NNSA has removed fissile material from some sites, and plans to dispose of a large fraction of its plutonium and HEU stocks from dismantled weapons. But after planned disposal is complete, the nation will still have enough fissile material for some 13,000 weapons. The United States should declare some of this plutonium and HEU to be excess to military needs, and dispose of it safely and expeditiously.
- The United States should speed up the downblending of HEU already declared as excess to LEU, which can be used to fuel reactors or produce medical isotopes.
- The NNSA should move any Category I HEU—that is, all but the smallest amounts—still at the weapons laboratories and other sites to the Y-12 National Security Complex, and consolidate plutonium storage at the smallest possible number of sites.
- The NNSA's planned method for disposing of plutonium—using it to manufacture mixed-oxide (MOX) fuel for use in commercial power reactors—entails significant security risks. The NNSA should cancel the MOX program and embed excess plutonium in a stable glass or ceramic form suitable for disposal in a geologic repository.

**The administration and Congress will make key decisions on the nuclear weapons complex over the next few years. Toward that end, this report examines the essential missions of the complex, considers its key challenges, and suggests critical near-term and long-term steps.**

### Dismantling Warheads and Verifying Further Reductions in Nuclear Arsenals

The United States has made major cuts in its deployed and reserve stockpiles of nuclear weapons, and the Obama administration is pursuing further reductions linked to cuts in Russia's nuclear stockpile. Such reductions are just as important to the nation's long-term security as maintaining the existing stockpile.

- The United States should ensure that it has the capacity to dismantle retired weapons and verify future reductions in nuclear arsenals.
- When planning life extension programs for nuclear warheads, the NNSA should include the need to dismantle retired weapons expeditiously.
- Congress should increase funding for research on verifying deeper nuclear arms reductions, including warhead-level verification.

## CHAPTER 1

# Introduction

The United States seeks to maintain a nuclear arsenal that is reliable, safe from accidents, secure from unauthorized use, and no larger than needed to protect its security and that of its allies. Key to this enterprise is the nuclear weapons complex: the set of laboratories and facilities that research, design, produce, and maintain nuclear weapons.[1]

What type of complex is required to maintain the U.S. stockpile and meet related goals? It should have the facilities and resources to extend the life of U.S. warheads, assess their reliability and safety, understand the effects of aging and any weapons modifications, and retain key scientific and technical expertise. The complex also requires the capacity to dismantle retired weapons in a timely fashion and to develop methods for verifying further reductions in nuclear weapons, reflecting the nation's longer-term goal of eliminating them worldwide. And the complex must minimize security risks while storing, transporting, and disposing of weapons-usable materials.

**The nation relies on its Stockpile Surveillance Program to assess the reliability, safety, and security of its nuclear arsenal. Although this program is essential, the NNSA has not given it the attention it deserves.**

Finally, the complex must meet all these challenges in a time of limited resources. The goal is to create a complex that is viable for as long as required, but without unneeded capabilities or facilities.

A viable complex requires effective management and oversight. Belief is widespread that the National Nuclear Security Administration (NNSA)—the semi-autonomous agency within the Department of Energy (DOE) that oversees U.S. nuclear weapons—is not performing its job well.[2] In fact, the NNSA has been struggling to prioritize its work for some time. The Obama administration's initial plan for the nuclear weapons complex was to build two major weapons facilities—the Chemistry and Metallurgy Research Replacement–Nuclear Facility, and the Uranium Processing Facility—and a Mixed Oxide Fuel Fabrication Facility to dispose of plutonium from dismantled warheads. The administration's plan also included ambitious programs to extend the lifetime of several types of warheads. However, skyrocketing costs and constrained budgets have led the NNSA to reconsider its plans for all three facilities.

The agency has delayed construction of the Chemistry and Metallurgy Research Replacement–Nuclear Facility—intended to allow an increase in plutonium pit production—by at least five years, and is developing an alternative strategy for the interim period. The NNSA recently revealed that after years of work on the design, the Uranium Processing Facility will have to be redesigned because it cannot accommodate the needed equipment, raising costs and delaying construction. And the agency just announced that it will slow construction of the Mixed Oxide Fuel Fabrication Facility and review other plutonium disposal strategies.

Meanwhile, a program to extend the life of the W76 warhead will not meet its schedule or budget. The estimated cost of the life extension program for the B61 bomb has jumped from $4 billion to $8 billion to $10 billion. And plans for extending the life of the W78 warhead entail even more complicated and costly modifications.

The administration and Congress will make key decisions on these and other programs over the next

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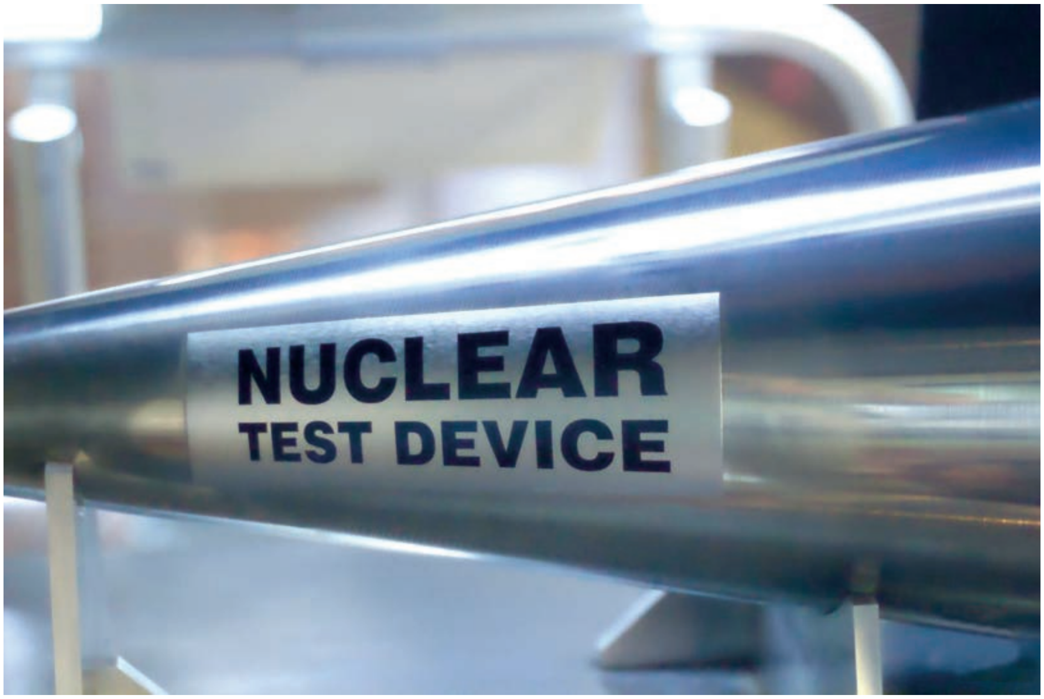
[1] Lawrence Livermore, Los Alamos, and Sandia have traditionally been referred to as the nuclear weapons laboratories, and we do so in this report. They have been formally renamed the National Security Laboratories.

[2] The new Congressional Advisory Panel on the Governance of the Nuclear Security Enterprise is considering how to revise the NNSA's governance structure. Although that effort is important, it is beyond the scope of this report.



**Scale model of a nuclear weapon resting on a diagnostic rack or "jewel rack" used for weapons testing at the Nevada National Security Site. The model was built by the Los Alamos National Laboratory, Los Alamos, NM.**

few years. Making smart choices will require paying strict attention to priorities.

This report examines the essential missions of the U.S. nuclear weapons complex, considers its key challenges, and recommends critical steps for the administration and Congress. These key challenges include:

**Extending the life of the nuclear arsenal.** U.S. weapons were not designed for a specific lifetime and do not expire at a certain age, but some components degrade as they age. To ensure that they remain reliable, safe, and secure for another 20 to 30 years, U.S. weapons have undergone or will undergo a life extension program or will be replaced with a different warhead.

The life extension program can also be used to modify the warheads to increase their safety or security, and the nation's weapons laboratories are eager to do so. However, extensive modifications can actually reduce the reliability of the weapons, given that the nation no longer uses explosive nuclear testing, and will make life extension programs more costly.

Chapter 2 explores the facilities the nation actually needs to complete these life extension programs.

**Ensuring robust surveillance.** The nation relies on its Stockpile Surveillance Program to assess the reliability, safety, and security of its nuclear arsenal.[3] Under that program, the NNSA removes some of each type of warhead from the stockpile each year, and subjects those warheads to a wide variety of non-nuclear tests. The agency also tests weapons components and materials. After removing the nuclear materials, the military also flight-tests weapons of each type.

Although this program is essential, the NNSA has not given it the attention it deserves. In recent annual reports on the reliability, safety, and security of the U.S. stockpile, the directors of the three national nuclear weapons labs have consistently expressed concerns about the overall direction of the surveillance program, as well as the limited number of surveillance tests they actually complete (GAO 2011c). The JASON group—scientific experts who advise the federal government on security—also found that the surveillance program is "becoming inadequate," and that a "revised" program was required to ensure the continued success of the Stockpile Stewardship Program (JASON 2009 p. 3).

In Chapter 3, we examine the steps the NNSA has taken to address these concerns, and consider critical actions that remain.

**"Rightsizing" stockpile stewardship.** When the United States ended nuclear explosive testing in 1992, it also stopped developing and deploying new nuclear weapons, focusing instead on maintaining existing

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[3] While stockpile surveillance is used to evaluate security measures intrinsic to warheads, the United States ensures the security of its nuclear weapons primarily through extrinsic measures: guards, gates, and guns.

Photo: Mark Kaletka, taken in the National Atomic Testing Museum in Las Vegas, Nevada

ones. To understand the effects of aging on these weapons, and any changes made to them during their life extension programs, the DOE created the Stockpile Stewardship Program, which is devoted to increasing the understanding of how nuclear weapons work.

The twin pillars of the program are advanced computing facilities used to model the performance of nuclear weapons, and experimental facilities that provide data to validate these computer models. In Chapter 4, we consider these facilities and their utility for different types of life extension programs, from those that make only modest modifications to warheads to those that are more extensive.

**The national nuclear weapons labs have long pursued research on verifying agreements to control nuclear weapons and prevent their proliferation, but their work on verification of further reductions should be strengthened.**

**Retaining a qualified workforce.** Officials at the nuclear weapons labs and outside analysts have stressed the need to maintain the scientific and technical expertise to extend the life of existing weapons, address any problems that may arise, and design modified weapons as needed. Chapter 5 examines the NNSA's efforts to attract and retain qualified personnel.

**Minimizing the risks of storing and disposing of weapons-usable material.** The nuclear complex stores and handles large amounts of plutonium and highly enriched uranium (HEU)—which can be used directly to make nuclear weapons—at several sites across the United States. Some of this material is no longer needed for nuclear weapons and will be disposed of. In Chapter 6, we evaluate plans and alternative methods for storing and disposing of these fissile materials.

**Dismantling warheads and verifying further reductions in nuclear arsenals.** The United States has made major cuts in its stockpiles of deployed and reserve nuclear weapons, and now has a backlog of weapons awaiting dismantlement. The facilities used to dismantle nuclear weapons are also used to disassemble and reassemble weapons during life extension programs, and these two missions compete for space. In Chapter 7, we consider ways to dismantle retired weapons more quickly while meeting the needs of life extension programs.

The national nuclear weapons labs have long pursued research on verifying agreements to control nuclear weapons and prevent their proliferation, but their work on verification of further reductions should be strengthened. Such research will help inform U.S. policy makers about the value of potential nuclear weapons treaties. In Chapter 7, we also show how to bolster such research.

CHAPTER 2

# Extending the Life of the U.S. Nuclear Arsenal

U.S. nuclear weapons were not designed for a specific lifetime, but some components need to be refurbished or replaced to ensure these weapons remain reliable, safe, and secure. Two types of U.S. weapon have already completed life extension programs to extend their lifetime for another 20 to 30 years: the W87 deployed on land-based missiles, and the B61-7 and -11 strategic bombs (see Table 1). A third type of weapon—the W76 warhead deployed on submarine-launched missiles—is in the production phase of its life extension program. Under current NNSA plans, the remaining types of weapons will undergo a life extension program, be replaced with a weapon of a new design, or be retired.

Current U.S. nuclear weapons generally have two stages: a primary and a secondary.[4] The primary includes a plutonium pit and conventional explosive that implodes the pit, leading to a fission explosion. The secondary is in a canned subassembly (CSA), a hermetically sealed container made of stainless steel. The CSA also contains the "interstage"—a substance that channels energy from the primary to ignite the secondary. The primary, secondary, and interstage constitute the nuclear explosive package.

When a weapon is detonated, a mixture of tritium and deuterium gases is injected into the hollow core of the plutonium pit just before the implosion begins. This causes a higher percentage of the plutonium to

**Table 1.** Life Extension Programs for the U.S. Nuclear Arsenal

| Current Weapons | Planned Weapons | Development | Production |
|---|---|---|---|
| **W87 (ICBM warhead)** | | | Completed in 2005 |
| **B61-7 and -11 (strategic bombs)** | | | Completed in 2008 |
| **W76 (SLBM warhead)** | W76-1 | FY 1998–FY 2009 | FY 2009–FY 2019 |
| **B61-3/4/7/10 (strategic/tactical bombs)** | B61-12 | FY 2009–FY 2019 | FY 2019–FY 2023 |
| **W88 (SLBM warhead)** | W88-Alt 370 | FY 2013–FY 2019 | FY 2019–FY 2023 |
| **W-80 (ALCM warhead)** | ALCM warhead | FY 2013–FY 2024 | FY 2024–FY 2030 |
| **W78/W88-1 (ICBM/SLBM warheads)** | IW-1 | FY 2011–FY 2021 | FY 2025–FY 2036 |
| **W87/88-1 (ICBM/SLBM warheads)** | IW-2 | FY 2021–FY 2031 | FY 2031–beyond FY 2038 |
| **W76-1 (SLBM warhead)** | IW-3 | FY 2027–FY 2037 | FY 2037–beyond FY 2038 |
| **B61 (strategic/tactical bombs)** | | FY 2033–beyond FY 2038 | |
| **B83 (strategic bomb)** | | | |

**NOTES:** According to the NNSA, B61-12 production is scheduled to run from FY 2019 to FY 2023 (NNSA 2013a). But according to the DOD's Office of Cost Assessment and Program Evaluation, production will begin in 2022 and end in 2028 (see Miller and Ho 2012; Young 2012). While the Nuclear Weapons Council has not determined the IW-2 and IW-3 warheads, the joint DOD/NNSA Enterprise Planning Working Group projects them to be the W87/88 and W76-1 life extensions, respectively. The B83 bomb will almost certainly be retired once production of the B61-12 is complete.

(ICBM = intercontinental ballistic missile; SLBM = submarine-launched ballistic missile; ALCM = air-launched cruise missile; IW = interoperable warhead)

Source: NNSA 2013a.

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[4] Some U.S. weapons have more than one option for the size of the nuclear explosion, or yield. Options with small yields may use only the primary stage.

fission, creating a larger primary explosion. Tritium-filled reservoirs and some other components of a weapon, including batteries, must be replaced regularly.

A warhead also includes hundreds of non-nuclear components, such as those in the arming, firing, and fuzing mechanisms. These components can be fully tested and replaced during life extension programs. The Kansas City Plant in Missouri produces or procures more than 100,000 such components annually, while Sandia National Laboratories in New Mexico designs them and produces the remainder. The NNSA is moving all activities at the Kansas City Plant to the National Security Campus, a new facility nearby, over the next year.

**Whether new pits are needed for warhead life extension programs depends on two factors: the lifetime of plutonium pits, and whether existing pits are replaced with newly built pits from a different warhead or with newly designed pits.**

The NNSA also plans to revamp or build new facilities for producing plutonium pits at Los Alamos National Laboratory in New Mexico, CSAs at the Y-12 National Security Complex in Tennessee, and conventional explosives at the Pantex Plant in Texas. In this chapter we discuss plans for life extension programs, and analyze the need for these new facilities, as well as plans for increasing the production of tritium.

## Life Extension Programs

Each life extension program the NNSA has under way or planned includes one or more of three approaches to the warhead's nuclear components:

- *refurbishment*, in which nuclear components are refurbished or rebuilt;
- *reuse*, in which nuclear components are replaced with surplus or newly built components from a different warhead that had previously undergone nuclear explosive testing; and
- *replacement*, in which nuclear components are replaced with newly designed ones that have not undergone nuclear explosive testing.

It is important to note that under the reuse option, each component would have previously undergone nuclear explosive testing but may not have been tested together with other key components of the new design. And the new warhead would not have been tested in its complete configuration. For example, the NNSA could use a primary from one warhead type and a secondary from another warhead type, as long as the components were from weapons that previously underwent nuclear explosive testing. Such modifications to the nuclear explosive package that deviate from previously tested designs could reduce the reliability of the weapon. Making extensive modifications would also increase the cost of the life extension program.

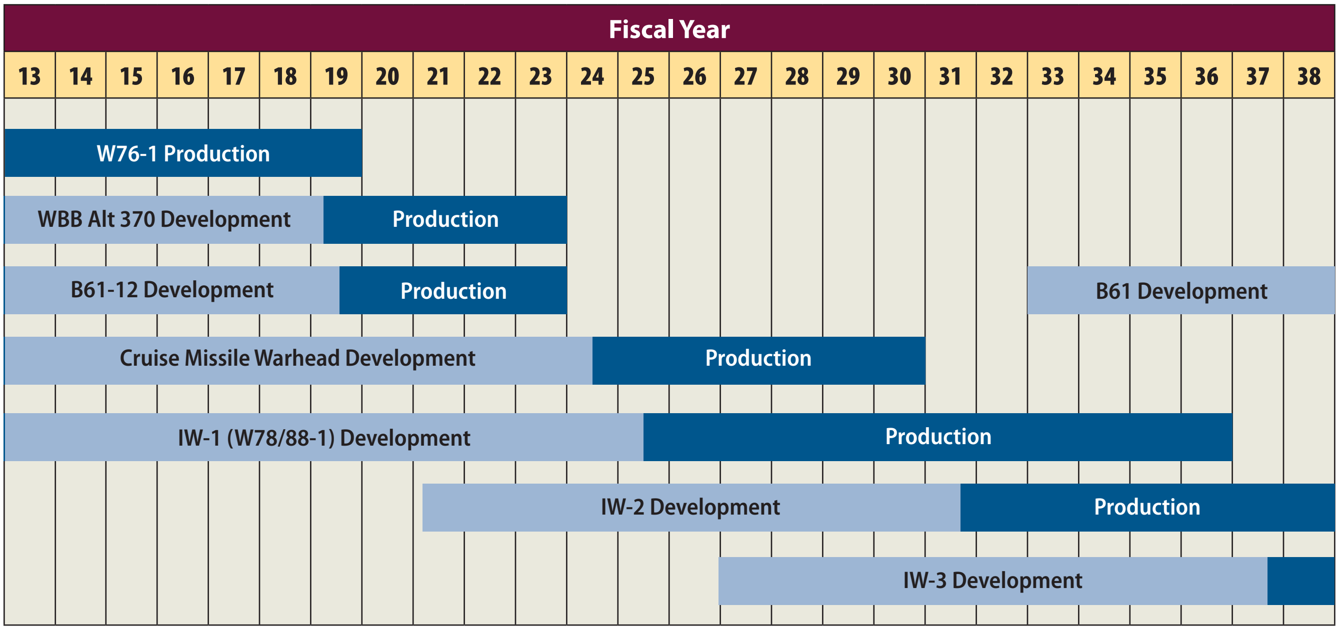
If the NNSA modified a component that had previously been tested, that would constitute a replacement strategy. Some types of modifications might make it difficult to certify that the weapon is reliable.

One reason the NNSA is interested in the reuse and replacement options is to modify the warheads

The new National Security Campus at the Kansas City Plant, 2011. Construction is complete and the facility will be fully occupied in 2014.

Photo: NNSA News

**Figure 1. Life Extension Programs for U.S. Nuclear Warheads**



**NOTES:** The W87 warhead, deployed on land-based missiles, and the B61-7 and 11 bombs completed their life extension programs in 2005 and 2008, respectively. According to the NNSA, B61-12 production is scheduled to run from FY 2019 to FY 2023. But according to the DOD's Office of Cost Assessment and Program Evaluation, production will begin in 2022 and end in 2028 (see Miller and Ho 2012; Young 2012).

(Alt = alteration; IW = interoperable warhead)

Source: NNSA 2013a.

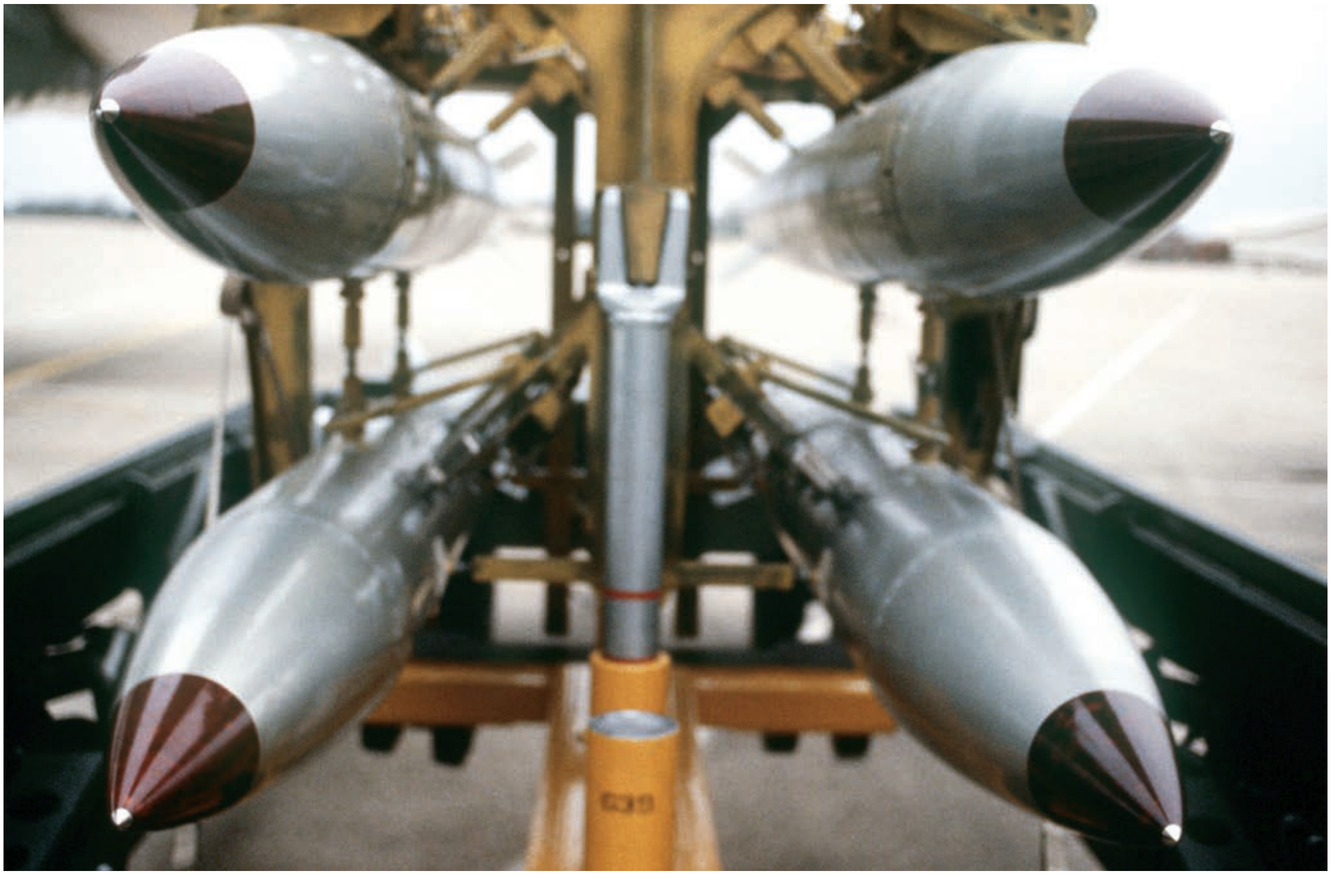
to increase their safety or security. For example, using insensitive high explosive rather than conventional high explosive to initiate the implosion of the primary would decrease the risks of accidental plutonium dispersal and nuclear detonation. To increase its safety, the life extension program for a warhead that uses a conventional high explosive could therefore reuse an existing design of a primary with an insensitive high explosive. Again, such modifications could lead to reduced reliability.

Some types of safety and security improvements would require a replacement strategy. For example, current weapons are not multi-point safe—a nuclear explosion would occur if the high explosive was detonated at two or more points simultaneously. Adding multi-point safety, if it were possible, would require a primary that was different from those previously tested.

The 2010 Nuclear Posture Review stated that the United States will give strong preference to the refurbishment and reuse options, and that any replacement of nuclear components with newly designed ones requires specific authorization from the president and Congress. The review also stated that the United States "will not develop new nuclear warheads," and that life extension programs "will not support new military missions or provide for new military capabilities" (DOD 2010b p. xiv). In contrast, the NNSA's FY 2014 Stockpile Stewardship and Management Plan states that the "NNSA will not develop new nuclear warheads or provide new military capability, *except* [emphasis added] to improve safety, security and reliability" (NNSA 2013a p. 1–5).

The Nuclear Weapons Council—a joint Department of Defense (DOD) and DOE body that oversees the process for managing the stockpile and provides policy guidance—has endorsed a "25-year baseline plan" that "identifies the path toward a long-term stockpile end state" (Harvey 2013 p. 3). This plan—dubbed 3+2—would replace the seven types of weapons in today's arsenal with three "interoperable" ballistic missile warheads and two "interoperable" air-delivered weapons (Figure 1). (An interoperable warhead would have nuclear components that could be deployed on both submarine-launched and land-based missiles, whereas the interoperable air-delivered weapon would have nuclear components that could be deployed on cruise missiles and as bombs. The non-nuclear components would vary by delivery system [NNSA 2013a].)

If the United States proceeds with the 3+2 plan and replaces existing warhead types with significantly modified ones, this would fly in the face of its stated intention to not develop new nuclear warheads, and have negative international political repercussions.



**Four B61 nuclear gravity bombs on a bomb cart at Barksdale Air Force Base in Louisiana.**

**FINDING**

- Creating new weapon types—even if they only use weapon components of previously tested designs—would be viewed by many as violating the administration's pledge not to develop or deploy new nuclear weapons, and could generate concerns about weapon reliability.

**RECOMMENDATION**

- The NNSA should give strong preference to refurbishing or remanufacturing existing weapon types.

## Does the United States Need a New Facility to Produce Plutonium Pits?[5]

The United States produces pits at the Plutonium Facility at Los Alamos. Annual capacity is 10 to 20 pits, according to the NNSA. According to the FY 2014 Stockpile Stewardship and Management Plan, the Nuclear Weapons Council called for achieving a capacity of 30 pits per year by 2021, and "up to 80 pits per year as early as 2030" (NNSA 2013a p. 1-2). However, according to congressional staff, the goal of 80 pits per year is not based on a specific requirement.

In recent testimony before Congress, Pentagon officials said that the NNSA needed the capacity to produce 30 pits annually by 2021 to fulfill the W78/W88 life extension program. The officials cited an eventual goal of 50 to 80 pits annually, but set no date or rationale. The officials also testified that "we are now confident that we can reuse plutonium pits as we implement these life extension programs" (U.S. Senate 2013a p. 16).

Until early 2012, the NNSA planned to acquire the capacity to produce 50 to 80 pits a year by completing the Chemistry and Metallurgy Research Replacement Project at Los Alamos. That project was designed to replace the Chemistry and Metallurgy Research Facility, where scientists analyze materials used in nuclear weapons, particularly plutonium.

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[5] This section draws on Gronlund and Young 2012.

Photo: Department of Defense/Wikimedia Commons

The project consisted of two phases. The first is the completed Radiological Laboratory/Utility/Office Building. The second was the planned Chemistry and Metallurgy Research Replacement–Nuclear Facility, to be located next to the existing Plutonium Facility. Those two facilities would be connected by an underground tunnel and would share a vault that could hold up to six metric tons of plutonium. The Plutonium Facility would continue to produce all pits, but would move some other activities to the Nuclear Facility, and move some materials to the shared vault, allowing pit production to expand to 50 to 80 per year. The NNSA estimated in 2010 that the Nuclear Facility would cost $3.7 billion to $5.9 billion—a six- to nine-fold increase over the $660 million estimate given to Congress in FY 2004.

The administration planned to simultaneously build another multibillion-dollar project, the Uranium Processing Facility (UPF) at the Y-12 complex, but the fiscal environment forced the administration to develop a new approach. After consulting with the weapons labs, the NNSA, and the DOD, the administration decided to proceed with the Uranium Processing Facility and delay the construction of the Nuclear Facility by at least five years, saving $1.8 billion over the next five years.

The administration noted that the "NNSA has determined, in consultation with the national laboratories, that the existing infrastructure in the nuclear complex has the inherent capacity to provide adequate support for these missions. Studies are ongoing to determine long-term requirements. NNSA will modify existing facilities, and relocate some nuclear materials" (DOE 2012b p. 41).

Administration officials say they can increase production capacity at the Plutonium Facility to 30 pits annually without the Nuclear Facility (U.S. Senate 2013a). However, other documents suggest that the NNSA could raise the rate to 50 pits annually without the new facility.

For example, when the Bush administration planned to build significant numbers of Reliable Replacement Warheads (RRW), which would have required new pits, the FY 2008 budget request noted that Los Alamos would "work to increase the pit manufacturing capacity to 30 to 50 net RRW pits by the end of FY 2012"—well before construction of the Nuclear Facility (DOE 2007b p. 199). And a Los Alamos document says that the Plutonium Facility could achieve a production capacity of 50 pits per year by 2020, also before completion of the Nuclear Facility (Kniss and Kornreich 2009).

In April 2013, administration officials testified before Congress about a possible alternative to the Nuclear Facility. Under a "modular" approach, the NNSA would build several smaller, single-purpose facilities—an approach that could be less costly, according to Los Alamos Director Charles McMillan (U.S. Senate 2013b). As of mid-April, the DOD and the NNSA were pursuing a 60-day "business case analysis," but no information about the capabilities, costs, or construction schedules of this strategy is publicly available (U.S. Senate 2013a).

**Because both pit lifetime and the future size of the arsenal are uncertain, it makes no sense to expand production capacity until it is needed.**

The alternative strategy could allow outright cancellation of the Nuclear Facility, although some members of Congress still want to build it. The FY 2013 defense authorization requires the facility to become fully operational by 2026, but also sets a $3.7 billion spending cap, and requires the DOE to provide a "detailed justification" for projected costs above the cap (U.S. House 2012 pp. 539–540).

The administration has offered no clear rationale for the number of pits it needs to produce annually over the long term. Whether new pits are needed for warhead life extension programs depends on two factors: the lifetime of plutonium pits, and whether existing pits are replaced with newly built pits from a different warhead or with newly designed pits.[6]

### The Lifetime of Plutonium Pits

Plutonium was first produced in significant quantities in the 1940s, and information on how its properties change with age is limited. Plutonium is radioactive: plutonium-239, the main isotope in nuclear weapons, has a half-life of 24,000 years, while that of plutonium-241 is 14.4 years. Plutonium emits alpha particles, which can cause microscopic damage to the crystalline

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[6] The NNSA removes weapons from deployment for surveillance and testing. For some types of warheads, testing involves destroying one pit per year and replacing the destroyed warhead with one from the reserve stockpile. Aside from the W88, many reserve warheads are available for such replacements. The NNSA recently completed a production run of W88 pits, including those it needs for destructive testing. Surveillance therefore does not require production of more pits.

structure of the plutonium metal. The accumulation of such damage could in principle cause a change in the material's properties, and in how it behaves in a nuclear weapon.

Before 2006, the DOE estimated that plutonium pits would have a lifetime of 45 to 60 years. The pits in today's nuclear arsenal were produced almost entirely from 1980 to 1989—meaning that they might need to be replaced as early as 2025. Concerns about how long the pits would remain reliable was one of the primary reasons that the NNSA initially sought to expand its ability to produce new ones, and a key justification for the proposed Reliable Replacement Warhead.

The NNSA is quickly accruing knowledge about the aging of plutonium and the lifetime of plutonium pits. Scientists at the weapons laboratories have been conducting accelerated aging experiments that each year provide data on 16 years of natural aging. These experiments have found that the plutonium crystal structure repairs the damage caused by the alpha particles through a process of "self-annealing."

In 2006, the JASON group assessed these data and, according to the NNSA, found that "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" (NNSA 2006). In other words, existing pits need to be replaced no earlier than 2080. That same year, the NNSA said it planned "to continue plutonium aging assessments through vigilant surveillance and scientific evaluation, and the weapons laboratories will annually re-assess plutonium in nuclear weapons, incorporating new data and observations" (NNSA 2006).

In December 2012, Lawrence Livermore National Laboratory in California announced that its research shows that plutonium has a lifetime of at least 150 years (Heller 2012). Los Alamos responded that "it's important to note that this study of plutonium aging is only one area of many that could determine pit lifetimes. Extending the observations from plutonium aging as representative of pit lifetimes neglects to take into consideration all of the other factors and could be easily misunderstood" (Clark 2012). Thus, while plutonium remains stable for at least 150 years, further research is needed to make sure the same holds true for pits.

If pits last 150 years or more, there is no need to replace aging pits for the foreseeable future, and no rationale for expanding production capacity beyond the existing 10 to 20 annually for this purpose. Even if the NNSA finds that pits will last only 100 years and that all need to be replaced by 2089, production capacity of 50 per year would be adequate.

The NNSA could replace all existing pits by 2089 if it started doing so in 2019, based on the agency's conservative assumption that the U.S. stockpile will remain at 3,500 warheads. However, the United States is likely to reduce its arsenal in coming decades. In that case, the NNSA could either wait longer to begin producing replacement pits (Table 2) or reduce the annual rate of production (Table 3).

Thus, even under the most conservative assumptions about pit lifetime and arsenal size, there is no need to expand pit production capacity beyond 50 per year to replace aging pits. Because both pit lifetime and the future size of the arsenal are uncertain, it makes no sense to expand production capacity until it is needed.

**Table 2. Replacing All Plutonium Pits by 2089, Assuming 50 Pits per Year and a Pit Lifetime of 100 Years**

| Total U.S. nuclear warheads in 2089, deployed and reserve | Year that replacement production should begin |
|---|---|
| 100 | 2087 |
| 500 | 2079 |
| 1,000 | 2069 |
| 2,000 | 2049 |
| 3,000 | 2029 |
| 3,500 | 2019 |

**Table 3. Required Annual Pit Production Capacity, Assuming a Pit Lifetime of 100 Years**

| Total U.S. nuclear warheads in 2089, deployed and reserve | Required average annual pit production, starting in 2019 |
|---|---|
| 100 | 2 |
| 500 | 8 |
| 1,000 | 15 |
| 2,000 | 29 |
| 3,000 | 44 |
| 3,500 | 50 |

Table 4. **Number of U.S. Warheads under Various Scenarios**

| | Current | | Under New START | | After Life Extension Programs, under New START | | After Life Extension Programs, with 1,000 deployed strategic weapons | |
|---|---|---|---|---|---|---|---|---|
| | Deployed | Reserve | Deployed | Reserve | Deployed | Reserve | Deployed | Reserve |
| **W78** | 210 | 400 | 150 | 150–460 | | | | |
| **W88** | 384 | 0 | 384 | 0 | | | | |
| **W87** | 250 | 300 | 250 | 250–300 | | | | |
| **IW-1 & IW-2** | | | | | 784 | 400–760 | ~500 | ~300–500 |
| **Total IW-1 & IW-2** | | | | | ~1,200–1,550 | | ~800–1,000 | |
| **ALCM** | 200 | 328 | 200 | 200–328 | 200 | 200–328 | ~130 | ~130–200 |
| **Total ALCM** | | | | | ~400–500 | | ~250–350 | |

(ALCM = air-launched cruise missile; IW = interoperable warhead)

Source: Hans Kristensen, Federation of American Scientists, private communication.

### New Pits for Life Extension Programs

As noted, life extension programs for nuclear warheads could entail reusing existing pits, or producing new pits based on an existing design or a new one. The NNSA's life extension programs for the W76 and the B61-3/4/7/11 entail refurbishing existing pits rather than building new ones. (The NNSA did not win approval for modifying the B61's nuclear explosive package significantly, but would have used the existing pits even if it had won approval.)

Production of the warhead for an air-launched cruise missile and the first two interoperable warheads (IW-1 and IW-2) is slated to take place over the next 25 years. These programs could create a need for newly produced pits. The first interoperable warhead, IW-1, will be the W78/88-1 life extended warhead. While the Nuclear Weapons Council has not made a determination about the IW-2 or IW-3, the joint DOD/NNSA Enterprise Planning Working Group assumes they will be the W87/88 and W76-1 life extension programs, respectively (NNSA 2013a).

How many interoperable warheads would the United States need to replace the W78, W88, and W87 warheads? It now deploys 210 W78 warheads and maintains another 400 in reserve. Under the 2010 New START agreement with Russia, the number of deployed W78 warheads will likely fall to 150 by 2018, allowing the reserve to expand to 460 (Kristensen and Norris 2011). However, the United States could cut the reserve force of W78 warheads along with the deployed ones—to perhaps 150. Thus, the reserve force could range from 150 to 460 weapons. Since one rationale for the 3+2 plan is to allow reductions in the hedge, the lower number is likely.

The United States now has roughly 400 W88 warheads, of which 384 are deployed, and this number is likely to remain the same under New START. It deploys 250 W78 warheads and maintains another 300 in reserve. It will likely continue to deploy 250 under New START, but could choose to reduce its reserve forces to 250 (Table 4).

Thus, the NNSA might replace some 1,200 to 1,550 W78, W88, and W87 warheads with the IW-1 and IW-2 warheads—assuming no further reductions in U.S. nuclear weapons beyond New START. Based on a DOD analysis, President Obama recently determined that the United States needs no more than 1,000 to 1,100 deployed strategic weapons, rather than the 1,550 allowed under New START. This suggests that the total number of IW-1 and IW-2 warheads will instead be 800 to 1,000.

In addition, the United States deploys 200 air-launched cruise missiles and maintains another 328 in reserve. It will likely retain the 200 deployed weapons under New START, but could cut the reserve force to 200, for a total of 400 to 528 weapons. If the United States makes further modest reductions to 1,000 deployed strategic weapons, the total number of cruise missile warheads might instead be 250 to 350.

Thus, assuming further modest reductions in the U.S. nuclear arsenal during the next 25 years, the NNSA might produce some 1,050 to 1,350 IW-1, IW-2, and air-launched cruise missile warheads. If all pits were newly produced, the NNSA would need an average annual production rate of roughly 40 to 55 pits.

However, the NNSA is unlikely to require all new pits, so a lower production rate will suffice. According to the FY 2014 Stockpile Stewardship and Management Plan, the NNSA recently completed a scoping study on interoperable warheads and "options focused on developing two unique NEPs [nuclear explosive packages], one incorporating reuse pits and one using remanufactured pits" (NNSA 2013a p. 2–18).

If the United States makes no reductions beyond New START in the next quarter-century, the NNSA might instead produce some 1,600 to 2,100 IW-1, IW-2, and air-launched cruise missile warheads. If all pits were newly produced, the NNSA would need an average annual production rate of roughly 60 to 80 pits. Again, it is unlikely that the NNSA would produce new pits for all three weapon systems, so an annual production capacity of fewer than 50 pits should also be adequate in this case.

**The NNSA recently removed all significant quantities of plutonium from Livermore in an effort to consolidate weapons-usable fissile material, so reintroducing plutonium there would undermine that effort.**

### Hedging against an Uncertain Future

New facilities for producing nuclear weapons "will be put in place to surge production in the event of significant geopolitical 'surprise,'" according to the 2010 Nuclear Posture Review (DOD 2010b p. 43). This expanded production capacity is intended to hedge against a resurgent Russia or an emboldened China. However, this rationale is not a sound one for expanding U.S. pit production capacity now, for several reasons.

First, any significant geopolitical shift would not be a surprise. A Russian or Chinese attempt to alter the strategic balance would require a massive effort that the United States would readily detect, giving it more than enough time to respond, if necessary.

Second, reserve nuclear warheads at least partly offset any U.S. need for a surge production capacity. And third, the nation already stores more than 14,000 pits from dismantled nuclear weapons at the Pantex Plant in Texas, which could be used to build more warheads if such a need emerged. Doing so would presumably take much less time than building new pits.

As the 2010 Nuclear Posture Review notes, 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" (DOD 2010b p. 15). An arsenal far smaller than the 1,550 nuclear weapons the United States will deploy under New START would deter Russia and China, regardless of the size of their arsenals.

### Bottom Line on the Need for More Capacity to Produce Plutonium Pits

Looking ahead 25 years, we find that the only plausible need to increase production capacity above today's level of 10 to 20 pits per year is to support programs for the IW-1, IW-2, and new air-launched cruise missile warheads—and then only if they use newly built pits. Based on NNSA planning, it is unlikely that all three warheads will use newly built pits. Under the assumption that the United States makes modest reductions in its nuclear arsenal over this time period—to between 1,000 and 1,100 deployed strategic weapons and a comparable reserve force—an annual production capacity of fewer than 50 pits would be enough, and could be attained without building the new Nuclear Facility.

Congress might not approve production of an interoperable warhead, as it would be widely seen as a new warhead design even if it used existing primaries and canned subassemblies. In 2008, Congress denied funding for the Reliable Replacement Warhead partly because it would have entailed designing and building a new warhead. More recently, Congress expressed serious concern about the NNSA's proposals for significant changes to the B61's nuclear explosive package, even though these options would have used the existing B61 pit. There is also evidence that the Navy may not be interested in an interoperable warhead. A September 2012 memo on the W78/W88 program from the undersecretary of the Navy to the chair of the Nuclear Weapons Council notes that "we do not support commencing the effort at this time" (DOD 2012).

### Other Roles for the Nuclear Facility

Beyond supporting more pit production at the Plutonium Facility, the proposed Nuclear Facility at Los Alamos would take on the materials characterization and analytical chemistry now performed at the Chemistry and Metallurgy Research Facility to investigate the properties of plutonium and other weapons materials. That work involves up to kilogram quantities of plutonium.

The first phase of the Chemistry and Metallurgy Research Replacement Project, the already completed Radiological Laboratory, is able to perform much of this work. Initially the lab was qualified to handle only small amounts of plutonium, limited to 8.4 grams at a time (NNSA 2010a). Based on a reexamination of the current international safety standards, NNSA officials determined that the lab could handle 34 to 39 grams of plutonium at a time (U.S. Senate 2012a). The Plutonium Facility as it is now configured can also handle some work on kilogram quantities of plutonium, and could potentially be modified to expand its capacity for this work.

If necessary, work involving kilogram quantities of plutonium could also take place at the Device Assembly Facility at the Nevada National Security Site, which is qualified to work on such quantities of fissile materials and has plenty of available space. However, this option would bring plutonium to a site where there is none on a regular basis now. (Subcritical nuclear tests using plutonium occur at the Nevada Site, but no more than once or twice a year.)

The NNSA is also considering using the Superblock facility at Lawrence Livermore for materials characterization and analytical chemistry on plutonium samples. The agency recently removed all significant quantities of plutonium from Livermore in an effort to consolidate weapons-usable fissile material at fewer locations, so reintroducing plutonium there would undermine that effort.

## FINDINGS

- Production capacity could expand to 50 pits annually even without the new Chemistry and Metallurgy Research Replacement–Nuclear Facility, according to NNSA documents.
- Plutonium pits last at least 100 years, and potentially much longer. Even under the conservative assumption that no further cuts in the U.S. arsenal will occur, expanding production capacity beyond 50 pits per year to replace aging pits is unnecessary. As both pit lifetimes and the future size of the arsenal are uncertain, expanding production capacity beyond 10 to 20 pits per year makes no sense until there is a clear need.
- Looking ahead 25 years, the only plausible need to increase production capacity above the existing 10 to 20 pits per year is to support production programs for the IW-1, IW-2 and air-launched cruise missile warheads—and then only if they use newly built pits. Based on NNSA planning, all three warheads are unlikely to use newly built pits. In that case, if the United States makes modest reductions in its nuclear arsenal over this time period—to between 1,000 and 1,100 deployed strategic weapons and a comparable reserve force—an annual production capacity of fewer than 50 pits would be enough, and could be attained without building a new Nuclear Facility.


Radiological Laboratory/Utility/Office Building at Los Alamos National Laboratory, 2013.

## RECOMMENDATION

- The administration should cancel plans for the Chemistry and Metallurgy Research Replacement–Nuclear Facility at Los Alamos National Laboratory, and develop an alternative plan for work with plutonium that minimizes the number of sites that store and handle it.

## Is the Uranium Processing Facility Appropriately Sized?

As noted, a canned subassembly is a hermetically sealed container with a stainless steel shell that houses a warhead's interstage and secondary. Warhead life extension programs may entail replacing or refurbishing either or both components.

### The Interstage

Whether the interstage was replaced or refurbished during life extension programs for the W87 warhead and the B61-7 and B61-11 strategic bombs is not publicly known. A portion of the interstage of the W76, containing a material with the codename Fogbank, is being replaced during its life extension program with

Photo: NNSA News

newly manufactured Fogbank material. The W78 and W80 warheads also reportedly contain Fogbank, which will presumably be replaced during their life extension programs.

Fogbank was initially produced in Building 9404-11 at the Y-12 National Security Complex. Production ended in 1989, and the building was later decommissioned. To manufacture Fogbank for the W76 life extension program, the NNSA built the Purification Facility at Y-12, which began operating in 2006. The NNSA initially had difficulties manufacturing Fogbank, but these have been resolved (LANL 2009).

**The NNSA expects that it will "reaccept" at least some CSAs as part of their life extension programs.**

### The Secondary

The secondary includes uranium, lithium hydride, and lithium deuteride. Although uranium is radioactive and emits alpha particles, its main isotopes have very long half-lives—those of U-235 and U-238 are 4.5 billion and 700 million years, respectively, for example—so aging from radioactive damage is not a concern. However, other aging mechanisms may be at play. The lithium compounds readily absorb moisture, and react with the water in humid air. That reaction produces free hydrogen, which in turn reacts with the uranium and produces a surface coating of uranium hydride.

To prevent these reactions, the secondary is baked in a vacuum to eliminate any moisture before the CSA is sealed. If this process is inadequate, a uranium hydride coating forms on the uranium metal from remaining moisture. Because designers did not expect nuclear weapons to remain in the stockpile for more than three decades, they may not have specified strict standards for moisture levels. Or Y-12 employees may not have paid careful attention to removing all the moisture from the CSAs before sealing them. And some secondary components outgas water molecules, so uranium hydriding could occur even if moisture was initially eliminated.

The extent to which uranium hydriding might affect the performance of the secondary is not publicly known. The United States did not use CSAs in its first- and second-generation thermonuclear weapons, which implies that uranium surface corrosion was acceptable for those weapons. And the secondary for the W-84 was not sealed in a can (Bonner, Lott, and Woo 2001). In any event, if a uranium hydride coating has formed, the Stockpile Surveillance Program would detect that anomaly, as Y-12 workers dismantle and examine several CSAs from deployed weapons each year. If they have detected such an anomaly, the labs must have concluded that it does not degrade performance, because they have certified U.S. nuclear weapons as reliable each year. Preventing further surface hydriding could help sustain the continued reliability of the secondaries, and that would not require dismantling them: each CSA has a tube that can be opened for additional baking.

However, a weapon undergoing a life extension program is expected to remain reliable for another 20 to 30 years. Even if no evidence suggests that uranium hydriding will be a problem, proving that this will remain the case for another several decades may not be possible. In other words, remanufacturing may not be required now but may be a precautionary step to help sustain reliability for another two to three decades. According to a Y-12 spokesperson, the life extension programs for the W87, B61-7, and B61-11 included remanufacturing the uranium components (Munger 2012). Whether that was required, precautionary, or unnecessary is not publicly known. Remanufacturing CSAs might be unnecessary, but the NNSA may simply want to retain the capability to do so.

The NNSA expects that it will "reaccept" at least some CSAs as part of their life extension programs, by assessing their components and reusing those that are in good shape. That would not only obviate the need for CSA production but would enhance security, because the NNSA would not have to ship CSAs from Pantex to Y-12 for dismantling and refurbishing. Pantex plans to reaccept CSAs for the B61-12, W78, and W80-1 life extension programs (B&W Pantex 2012).

### The Uranium Capabilities Replacement Project

The United States produces all the secondaries and CSAs for its nuclear weapons in Building 9212 at Y-12. This building originally dates from 1945, and the Defense Nuclear Facilities Safety Board has expressed concern about continuing its operations for another decade. Uranium operations also occur in several other aging buildings at Y-12. Annual production capacity at Y-12 is now 125 secondaries, assuming a single shift and a five-day work week.[7]

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[7] Production capacity of 125 secondaries refers to the "more difficult systems that have been produced in the past or could be produced in the future." For "less difficult" secondaries, the capacity is about 160 secondaries (NNSA 2011b p. 1-12).

As part of its Uranium Capabilities Replacement Project, the NNSA plans to build a new UPF at Y-12. Phase I of the project will consolidate activities that now occur in different parts of Building 9212, including uranium casting and uranium chemical processing. Phase II will incorporate the activities of Buildings 9215 and 9998, including uranium metal-working, machining, and inspection. Phase III will add the capabilities of Building 9204-2E, including radiography, assembly, disassembly, quality evaluation, and production certification for secondaries.

That consolidation means that the high-security area will shrink from about 150 acres to 15 acres, reducing security costs. According to the NNSA, "With the use of advanced security surveillance systems and a smaller security area, the EU [enriched uranium] protective force will be reduced by 40–60 percent" (NNSA 2011b p. 1-8).

When planning for the Uranium Processing Facility began in 2004, the estimated cost of construction was $600 million to $1.1 billion. In 2007, when formal design work began, the estimate rose to $1.4 million to $3.5 billion. In 2011, after having completed 45 percent of the facility, the NNSA reported a new estimate of $4.2 billion to $6.5 billion. And a 2011 study by the Army Corps of Engineers projected a cost of $6.5 billion to $7.5 billion (Munger 2011).

In October 2012, the NNSA announced that the building will need significant redesign to accommodate all the needed production equipment. The roof will be raised about 13 feet, the concrete foundation slab will be one foot thicker, and the walls will be 30 inches thick rather than 18 inches (DNFSB 2012a). Plans now call for the building to begin operating in 2021, but the redesign will further delay the project and increase its cost. And revised cost estimates likely reflect only Phase I.

## Options for the Uranium Processing Facility

The NNSA required that the UPF be capable of producing CSA components for two different weapons systems—and two life extension programs—simultaneously (DOE 2011b). The NNSA considered three options for the facility: (1) the UPF Alternative, a 388,000-square-foot building with an annual capacity of 125 secondaries; (2) the Capability-Sized UPF Alternative, a 350,000-square-foot building with a capacity of 80 secondaries; and (3) the No Net Production/Capability-Sized UPF Alternative, a 350,000-square-foot building with a capacity of 10 secondaries. The NNSA is proceeding with the second option.

Although the third option would entail producing many fewer secondaries than the second one, the buildings would be the same size, because building even one secondary requires a minimum amount of equipment and floor space. According to the Government Accountability Office, "An independent study found that most of the UPF's planned space and equipment is dedicated to establishing basic uranium processing capabilities that are not likely to change, while only a minimal amount—about 10 percent—is for meeting current stockpile size requirements" (GAO 2010c). Thus, once the equipment is in place, it is apparently adequate to build up to 80 secondaries a year, assuming one shift for five days a week. Production could presumably be doubled or tripled by adding shifts.

In developing the second option, the NNSA assumed a stockpile of about 1,000 deployed strategic nuclear warheads. If each secondary has a nominal lifetime of 25 to 30 years, an annual production capacity of 80 would allow NNSA to produce 2,000 to 2,400 secondaries during that time period—enough to support a deployed strategic arsenal of 1,000 weapons and a comparable reserve force.

According to the NNSA, the third option "would provide the minimum assembly/disassembly capacity which NNSA thinks would meet national security requirements" (NNSA 2011b p. 3-31). It would permit surveillance and dismantlement operations, and "would be available to produce any required refurbished or reused secondaries" (NNSA 2011b p. 1-17). But

**The Y-12 Plant in Oak Ridge, Tennessee, converts uranium-235 powder to metal discs or "buttons," which are then manufactured into weapons components.**

Photo: DOE

this alternative "would not support adding replacement or increased numbers of secondaries and cases to the stockpile" (NNSA 2011b p. 1-16).

That this alternative would meet national security requirements while producing only 10 new secondaries a year suggests that remanufacture during life extension programs will be unnecessary for the next 50 years—the lifetime of the planned UPF. Roughly 10 secondaries would be needed to replace those that are disassembled each year as part of the NNSA's surveillance activities that assess the continued reliability of the weapons in the arsenal. And even this modest level of production would be unnecessary if stockpiles of excess CSAs, or those from further cuts in the nuclear arsenal, could replace those destroyed for surveillance.

The B-61 life extension program will not use newly built CSAs, but building the capability-sized UPF would maintain this option for future life extension programs.

As noted, the NNSA is interested in building an interoperable warhead to replace W78s and W88s. The life extension program for the IW-1 warhead is now in the development phase in which the NNSA will decide which options are feasible and which ones it wants to pursue. The NNSA is slated to complete that phase in FY 2016, when it will have decided whether to use a refurbished CSA, reuse an existing CSA from a different warhead, or use a newly built CSA of either an existing or modified design. The Nuclear Weapons Council will then weigh in, endorsing some, all, or none of the modifications the NNSA proposes. And Congress could accept or reject the changes endorsed by the Nuclear Weapons Council. A final decision on the need for new CSAs for the IW-1 is therefore several years away. The same is true for the cruise missile warhead.

### Hedging against an Uncertain Future

As with plutonium pits, one rationale for an annual production capacity of 80 CSAs is to provide surge capacity in the event of a "geopolitical surprise." As noted above, such a surprise is not feasible, reserve weapons would allow a rapid increase in the deployed nuclear arsenal if needed, and the U.S. deterrent would remain robust even at far lower levels of deployed and reserve weapons. Acquiring a surge capacity is therefore not a reason to build a UPF with an annual production capacity of 80 CSAs.

### Other Roles for the UPF

Once all phases of the UPF are complete, the building will also be used to dismantle excess CSAs and remove the highly enriched uranium. Some of the HEU will be used to make fuel for the nuclear reactors that power all U.S. submarines and aircraft carriers. The NNSA has agreed to provide the Navy with HEU through 2050, which commercial entities use to make the fuel.

The United States has declared 374 tons of HEU excess to its defense needs, and will convert much of it to low-enriched uranium (LEU) for civil use. About 10 percent of excess HEU is down-blended to LEU at Y-12 for use as fuel in research reactors, or to produce medical isotopes. Y-12 is the primary provider of LEU for such reactors worldwide. Remaining excess HEU is shipped to the Savannah River Site in South Carolina or a commercial facility in Lynchburg, Virginia, to be down-blended for use as fuel in nuclear power reactors.

### FINDINGS

- The NNSA needs to replace the aging uranium facilities at Y-12.
- An annual production capacity of 10 nuclear secondaries would meet national security requirements, according to the NNSA.
- Planned production capacity of 80 CSAs per year would only be needed if the NNSA does not use existing secondaries for life extension programs for nuclear warheads.

### RECOMMENDATION

- The United States should build the Uranium Processing Facility. However, the administration should delay construction until the NNSA, the Nuclear Weapons Council, and Congress determine and publicly explain how much secondary-production capacity the nation needs to support the stockpile.

## Is the High Explosive Pressing Facility Appropriately Sized?

Chemical high explosive is a crucial component of nuclear weapons. It is part of the primary and is also used in other small components of the weapons, such as detonators and actuators.[8] The high explosive in the

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[8] Detonators ignite the high explosive surrounding the pit. The Detonator Fabrication Facility at Los Alamos produces detonators for the nuclear explosive package for the stockpile (NNSA 2010b). Actuators are part of the gas transfer valve in a nuclear weapon, which is part of the gas transfer system used to inject tritium into the imploding primary. These valves consist of a body, piston, and the actuator, which uses small amounts of high explosive that burns rapidly to create hot combustion gases to move the piston, releasing the tritium gas (Sandoval 2008).

primary of a nuclear weapon, called the main charge, is composed of two hemispheres that surround the plutonium pit (Lundberg 1996). When a weapon is detonated, the initiation system ignites a booster charge of high explosive, which then sets off the main charge (Heller 2010). When the main charge is detonated, it implodes the pit, compressing the plutonium to create a supercritical mass that leads to explosion of the primary.

The United States produces its main charges at Pantex, which has a production capacity of 1,000 pounds of specialty high explosive and 300 hemispheres per year—enough for 150 weapons (NNSA 2010b).[9] In August 2011, the NNSA broke ground on a new High Explosive Pressing Facility (HEPF) at Pantex to produce hemispheres. The facility is expected to cost $142 million and enter service in 2016, becoming fully operational by 2017 (U.S. House of Representatives 2011). The HEPF will increase Pantex production capacity to 2,500 pounds of high explosive per year. Pantex also plans to add a second press, expanding its hemisphere production capacity to 500 per year—enough for 250 weapons.

The original 2008 plan for the HEPF called for a production capacity of 1,000 hemispheres per year. According to its FY 2011 Performance Report, Pantex met its target of "developing proof-of-concept tooling and procedures for pressing multiple main charge high explosives simultaneous [sic] in the yoke press" (B&W Pantex 2011 p. 14). Once fully implemented, this capability would also expand the capacity of high explosive pressing by some 60 percent, according to the report. If this estimate is accurate, the new technique would increase the number of hemispheres that Pantex can produce at its existing facility from 300 to 480 per year—enough for 240 weapons. Annual production capacity at the new facility would similarly rise from 500 to 800 hemispheres—enough for 400 weapons.

A newly installed lathe at the Pantex Plant in Texas, used to machine high explosive parts for use in weapon life extension programs, 2012.

The new 45,000-square-foot HEPF will include the main pressing facility, a magazine storage area, and a ramp connecting the two (CH2M HILL n.d.). The HEPF will also include inspection, machining, staging, and radiography for high explosive, replacing several aging buildings at Pantex where these now occur. Consolidating these functions in one building will improve safety by reducing the need to move high explosive materials around the site. These activities will also move outside the high-security Protected Area, improving efficiency because moving high explosive can require restricting other operations (CH2M HILL n.d.; NNSA 2012c).

Is the new HEPF appropriately sized, given plans for the U.S. nuclear arsenal and life extension programs?

### The Need for High Explosive under Various Scenarios

High explosive is one of the better-understood materials used in nuclear weapons. Because it contains organic compounds, high explosive degrades over time. It can become less powerful, potentially undermining the effectiveness of weapons, and may also become more sensitive, and therefore less safe (DOE 1996d).

The NNSA has devoted a great deal of effort to understanding the aging process of high explosive and the conditions under which it will be effective and safe. The Stockpile Surveillance Program includes many inspections and tests—both destructive and nondestructive—on the high explosive in aging weapons. Surveillance of high explosive in main charges and boosters occurs at Pantex, while surveillance of high

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[9] Besides high explosive used in the main charge, Pantex also produces other small high explosive components for weapons. Los Alamos can also fabricate and process high explosive. The 1996 environmental impact statement for Stockpile Stewardship and Management, which considered how to best configure the nuclear weapons complex for its new mission of maintaining the stockpile without nuclear testing, proposed Los Alamos as one location for the high explosive mission, asserting that no new facilities would be needed. The Los Alamos high explosive facilities were originally built to produce high explosive for nuclear weapons in the 1950s (DOE 1996c). Los Alamos has updated its capability to process high explosive and produce high explosive components for hydrodynamic and other tests, and has produced prototypes of complex high explosive components. The lab can produce high explosive main charges and other components using processes similar or identical to those used at Pantex (NNSA 2008).

Photo: NNSA News

explosive in detonators and actuators occurs at Lawrence Livermore (Larson and Bishop 2004).

Testing measures the shape, density, and composition of the charge to verify that they remain within allowable limits, and checks that the high explosive retains its structural integrity and mechanical strength. Technicians also inspect high explosive removed from warheads for signs of chips, cracks, scratches, or discoloration (Larson and Bishop 2004). Scientists have observed a number of age-related changes, including swelling, migration of the plasticizer, degradation of the binder and mechanical properties, and rupture of adhesive bonds (Walter 1999).

**While work continues on how aging and environmental conditions affect high explosive over the longer term, scientists know it has a limited life span.**

While work continues on how aging and environmental conditions affect high explosive over the longer term, scientists know it has a limited life span and will need to be replaced at regular intervals, if weapons remain in the stockpile longer than originally anticipated. That means life extension programs will include replacing high explosive, and that the nuclear weapons complex needs to maintain the capacity to produce it.

A 1996 DOE report analyzed production needs for three sizes of arsenal: a base case of 3,500 deployed strategic nuclear weapons—the level allowed by the START II agreement, a “low case” of 1,000 deployed weapons, and a “high case” of 6,000 weapons. A START II–level stockpile would require the capacity to produce 150 sets of high explosive components each year; the low case, 50 sets; and the high case, 300 sets.

This prediction assumed a stockpile lifetime of 30 to 40 years, based on the known effects of aging on high explosive (DOE 1996c). The DOE also assumed that the Stockpile Surveillance Program would disassemble and inspect 120 sets each year. Of these, 110 would be rebuilt, and the remaining 10 destroyed during testing would need replacement. The low, base, and high cases would therefore require a total of 60, 160, and 310 sets, respectively, each year (Table 5).

The DOE report found that the cost of the capacity to produce 310 sets per year did not differ significantly from that of 160 under the START II base case. The NNSA therefore decided to plan for a capacity of 310 to acquire a contingency capability (DOE 1996d). Under New START, however, the United States will reduce the number of deployed strategic weapons to 1,550 by 2018. Given DOE estimates that 50 and 150 new sets of high explosive components would be required for arsenals of 1,000 and 3,500 deployed weapons, somewhat fewer than 100 new sets of components would be needed per year for a stockpile of 1,550 weapons under New START.

What’s more, in 1996, the year the study was conducted, the U.S. arsenal included 14 types of nuclear warheads (nine strategic and five non-strategic), while it now includes nine (eight strategic and one non-strategic), so the number of high explosive sets required to replace those destroyed during testing each year has likely

**Table 5.** Sets of High Explosive Components Needed under Various Scenarios

| | 1996 DOE Low Case (1,000 deployed weapons) | 1996 DOE Base Case (3,500 deployed weapons under START II) | 1996 DOE High Case (6,000 deployed weapons) | New START (1,550 deployed weapons) |
|---|---|---|---|---|
| New sets of high explosive produced each year to maintain stockpile | 50 | 150 | 300 | < 100 |
| New sets produced each year to replace those destroyed during stockpile surveillance | 10 | 10 | 10 | <10 |
| **Total** | **60** | **160** | **310** | **<110** |

dropped below 10. Annual production capacity required to maintain the New START arsenal will therefore be fewer than 110 sets of high explosive.

Several types of warheads are scheduled to undergo life extension programs between 2017, when the High Explosive Pressing Facility is scheduled to become fully operational, and 2038 (Figure 1, p. 8). The W76 life extension program will require some 1,200 warheads from FY 2009 through FY 2019, requiring roughly 110 sets of high explosive each year.

Some 400 B61-12 bombs are slated to begin production in FY 2019, and the NNSA plans to replace no more than 610 W78 and 550 W87 land-based warheads, 384 sea-based W88 warheads, and 528 W80 cruise missile warheads by FY 2038 (these are the numbers of weapons currently deployed and in reserve). While those schedules will likely slip, that means the NNSA plans to produce fewer than 2,472 life-extended weapons during that period—or fewer than 120 per year, on average.

If Pantex needs to produce 120 sets of high explosive for these life extension programs, and 10 sets to replace those destroyed during stockpile surveillance, it would need to produce a total of 130 a year. Yet the High Explosive Pressing Facility will be capable of making 250 to 400 a year—far more than required, even assuming no further cuts in the arsenal. That means there is no need to nearly double the amount of high explosive produced each year, or to build a second press.

**FINDING**

- The planned capacity for the new High Explosive Pressing Facility is greater than needed, even assuming no further cuts in the U.S. nuclear arsenal.

**RECOMMENDATION**

- The NNSA should defer building a second high explosive press until there is a demonstrated need for it.

## How Much Tritium Does the United States Need?

A radioactive isotope of hydrogen that contains two neutrons, tritium is rarely found in nature and must be produced artificially to provide an adequate supply. Tritium also has a short half-life of about 12 years and decays at a rate of roughly 5.5 percent a year, so it must be replaced regularly to maintain the required amount.

**Workers at the Tritium Extraction Facility at the Savannah River Site in South Carolina, 2005.**

All warheads in the nation's "active" stockpile contain tritium. This stockpile includes some 4,550 weapons, with roughly 2,000 deployed and 2,500 in reserve.

The amount of tritium needed for each type of warhead depends partly on how often the tritium reservoirs are replaced—"usually" every "few years" according to the DOD (DOD n.d. a).[10] DOD technicians perform these replacements in the field. Submarine-based warheads are less accessible than other types, and their reservoirs may be replaced only every dozen years, when a submarine is overhauled.

Tritium requirements also depend on the desired performance margin for each weapon—the ratio of the primary yield at minimum tritium levels to the yield required to ignite the secondary. A higher performance margin means greater reliability, up to a point.

The NNSA appears to be planning to increase the replacement interval and performance margin of at least some weapons during their life extension programs. According to the agency's FY 2014 Stockpile Stewardship and Management Plan, future gas transfer systems "will probably involve larger tritium loads than past weapons because they will be designed to last longer" (NNSA 2013a p. 2-23), and tritium production may need to increase by a factor of three to meet the new requirements.

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[10] Variable-yield weapons may include more than one reservoir, each containing the amount of gas needed for a desired yield.

Photo: DOE

Moreover, some members of the administration have suggested that the NNSA should move to a system of "15-year touches," where all warheads are inspected every 15 years, and all limited-life component replacements also occur on this schedule (UCS, AAAS, and Hudson 2011). In this case, the amount of tritium in reservoirs would need to be increased, to extend the effective lifetimes of the warheads from "a few" to at least 15 years. Increasing the replacement interval by 12 years would require doubling the amount of tritium in each reservoir—and thus the amount produced each year. However, removing 1,000 weapons from the active stockpile would provide some five years' worth of tritium for the remaining 4,000 weapons.

**The requirement for a five-year tritium reserve seems to be an artifact of earlier production methods: five years was the amount of time needed to restart a tritium production reactor at Savannah River.**

Besides the tritium in active stockpile weapons and the pipeline, a 1990 presidential directive requires that the United States maintain a five-year reserve supply of tritium. This requirement appears to still be in place. Of course, this reserve is also decaying at a rate of 5.5 percent a year, so it must be constantly replenished. Roughly one-third of annual tritium production goes to maintaining the five-year reserve.[11]

### Tritium Production Today

Until 1988, reactors at the Savannah River Site produced the tritium used in U.S. nuclear weapons. The last production reactor there was shut down in 1988 because of safety concerns.[12] As the United States reduced its number of nuclear weapons in the 1990s, it obtained sufficient tritium from retired weapons.

In 1995, the DOE decided that tritium from retired weapons would not provide an adequate supply, and considered several alternatives. These included restarting a Savannah River reactor, using an accelerator to produce tritium, and building a new reactor or purchasing a partially built one and dedicating it to producing tritium. In 1998 the DOE decided that producing tritium in commercial reactors would be more economical.

The requirement for a five-year tritium reserve seems to be an artifact of the earlier production method: five years was the amount of time needed to restart a tritium production reactor at Savannah River. But now that commercial nuclear reactors are producing tritium, such a large reserve may no longer be needed. The reserve requirements should be based on plausible disruptions in current production methods.

To produce tritium, some rods used to control the fission reaction in a nuclear reactor are replaced with tritium-producing burnable absorber rods (TPBARs). In these, boron is replaced with an isotope of lithium that produces tritium during the neutron absorption process (NRC 2011). The TPBARs are inserted into the reactor core during refueling, and irradiated for 18 months before being removed during the next refueling cycle. They are then shipped to the Tritium Extraction Facility at Savannah River for processing and tritium extraction.

All irradiation of TPBARs has so far occurred at the Tennessee Valley Authority's (TVA's) Watts Barr Unit 1 reactor. The NNSA has a contingency plan to use the TVA's Sequoyah Units 1 and 2 to irradiate more TPBARs.

The annual budget for tritium production—for replacing the 5.5 percent in weapons and the tritium reserve that decays each year—is roughly $65 million. These costs do not scale linearly with the rate of tritium production. The major costs of irradiating TPBARs in a reactor apply whether one or many are inserted, so irradiating more at that reactor does not greatly increase costs. On the other hand, costs could rise significantly if another reactor is needed to expand production.

The other major cost associated with tritium production is operating the Tritium Extraction Facility. Because the NNSA is producing less tritium than planned, the plant is idle for about nine months a year. Increasing tritium production would not greatly increase costs at the facility, nor would decreasing tritium production substantially decrease operating costs.

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[11] The reserve must be large enough so that at the end of five years, there is enough tritium to resupply the amount in weapons that has decayed during those five years. Thus, $R(1-f)^5 = W[1-(1-f)^5]$, where R is the amount of tritium initially in the reserve, W is the amount of tritium in weapons, and f is the decay fraction ($f = 0.055$). This yields $R/W \approx 1/3$.

[12] Reactors at the DOE's Hanford Site in Washington also produced smaller amounts of tritium.

### Challenges with Tritium Production

In theory, the existing system allows a great deal of flexibility in the amount of tritium produced. If more tritium is needed, more TPBARs can be irradiated at the Watts Bar Unit 1 reactor or the two reactors at the TVA's Sequoyah plant.

In practice, however, the program has been plagued by problems that have kept tritium production below planned levels. In particular, the amount of tritium leaking into the cooling water at the Watts Bar reactor is four times the expected level. Tritiated water is radioactive, and can be released into public water sources only in small quantities. To keep the amount of tritium in cooling water below regulatory limits, the NNSA has been irradiating fewer TPBARs than originally planned.

According to the GAO, "It is unlikely that anything less than a complete redesign of the TPBARs will solve the problem." However, because the NNSA does not fully understand what is causing the larger-than-predicted leakage, even a complete redesign may not work. In the interim, existing supplies of tritium in the stockpile and reserve "are unlikely to fulfill requirements for the time a complete redesign would take" (GAO 2010b p. 17). The GAO questioned whether the NNSA could increase tritium production in time to avoid dipping into the reserve.

The NNSA responded that it could meet near-term requirements by increasing the number of TPBARs irradiated to 544 per cycle until FY 2016. And indeed, the Watts Bar Unit 1 reactor is now irradiating that many—up from 240 in the previous cycle (DOE 2012b p. 145). Over the longer term, the NNSA said that irradiating about 1,500 TPBARs per cycle will "meet the planned steady-state requirement needed in FY 2017" (GAO 2010b p. 23). To fulfill that need, the agency is seeking approval from the Nuclear Regulatory Commission to increase the amount of tritium in the water released from Watts Bar and, as noted above, has a contingency plan to use the Sequoyah Units 1 and 2 reactors (DOE 2012b p. 149).

Another potential complication is that fuel for commercial reactors used to produce tritium for weapons must come from domestic sources, to avoid restrictions on "dual-use" materials. The DOE has used this rationale to support its decision to provide financial assistance to USEC, the domestic uranium enrichment company, and its American Centrifuge Plant in Ohio (DOE 2012f).

However, the United States produces plenty of LEU fuel from its own stocks of HEU that are excess to its weapons needs. While most of this HEU cannot be used for any military purposes, about 50 metric tons can be used for military purposes other than direct use in nuclear weapons, so fuel made from this HEU could be used in tritium-producing reactors. (See more on this in Chapter 6.) The NNSA currently plans to continue supplying HEU for tritium production until 2039 without the need for any additional enrichment capability (DOE 2013b p. 2-25).

### FINDINGS

- The NNSA's plans to expand tritium production to allow longer replacement intervals and greater performance margins will mean only marginally higher costs—unless a second or third reactor is needed, in which case costs could rise significantly.
- The requirement for a five-year tritium reserve dates from a time when the United States needed to restart a reactor to produce more tritium. Now that commercial reactors are producing tritium and production can expand more quickly, such a large reserve may no longer be needed. Reducing this reserve would also reduce the need for a second or third reactor.
- Fifty metric tons of HEU available for down-blending to LEU can be used for military purposes other than directly in nuclear weapons, so fuel made from this HEU could be used in tritium-producing reactors.
- There is no need to provide financial assistance to USEC or its American Centrifuge Plant to produce LEU to fuel tritium-producing commercial reactors.

### RECOMMENDATIONS

- The NNSA should reevaluate the requirement for a five-year tritium reserve.
- The NNSA should down-blend some of its large existing stockpiles of HEU to provide any fuel needed for tritium-producing reactors, and Congress should not fund USEC or its American Centrifuge Plant.

## CHAPTER 3

# Stockpile Surveillance: Assessing the Reliability and Safety of Nuclear Weapons

The nuclear weapons laboratories have had careful procedures for assessing the reliability and safety of U.S. nuclear warheads and bombs, and the viability of the security measures intrinsic to the weapons, for more than 50 years. Nuclear explosive testing has never played more than a minimal role in this work.

The United States used the great majority of its 1,054 nuclear explosive tests to explore experimental designs, test and perfect designs for weapons to be deployed, and study the effects of nuclear weapons. The nation used only 17 of these tests to confirm the reliability of already deployed weapons (Johnson 1995).[13] These 17 tests, conducted from 1972 to 1992, included one for each type of weapon in today's arsenal.

Although the 17 tests were successful, far more would be needed to provide any statistically meaningful data on the reliability of weapons in the stockpile. Using explosive nuclear testing to assess reliability has therefore never been practical. Instead, the NNSA inspects and extensively tests a sample of deployed weapons without using nuclear explosions. Workers also replace the fissile material in some of the bombs and warheads with non-fissile material or diagnostic equipment,

A B61 bomb being readied for a surveillance test at the Pantex Plant in Texas, 2006.

Photo: NNSA News

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[13] See also Gottfried 2000. Besides testing complete weapons, explosive nuclear tests also provided some data on the reliability of individual components. Fifty-one tests included one or more components from stockpiled weapons, and some tests used newly manufactured primaries.

and the military drops them from an airplane or launches them on a missile. Workers also test individual components. These methods form the basis of the Stockpile Surveillance Program, which began in 1958.

Until 2007, the DOE conducted Stage One testing: each year employees randomly selected a specified number of each type of deployed warhead and bomb for disassembly and testing. Beginning in the mid-1980s, the DOE removed 11 of each type each year, which provided 90 percent confidence that a defect that occurred in 10 percent of the weapons would be detected within two years.[14]

The DOE sent these 11 weapons to Pantex, where technicians disassembled and inspected them. Eight or nine were prepared for laboratory testing, and the remaining two or three were used in flight tests. Technicians also disassembled the nuclear explosive package of one of each type of warhead each year, destroying one plutonium pit in the testing process. Remaining warheads not expended in flight tests could be reassembled and returned to the stockpile.

The requirement that one pit of each warhead type be destroyed each year was the driving factor behind the decision in the mid-1990s to begin production of pits for the W88 warhead at Los Alamos.

The Rocky Flats Plant in Colorado had formerly produced all pits, but that facility was shut down in 1989 because of environmental and health concerns. The DOE had intended to build several thousand W88 warheads to replace the W76s, but manufactured only some 400 before the closure. Because the United States deployed an estimated 384 W88 warheads, this left only a small and shrinking reserve. In 2004, only one W88 pit was available to replace the one destroyed during testing that year. The NNSA therefore decided to develop the capacity to make pits at Los Alamos, which began producing W88 pits in 2007 after several years of effort.

Beginning in the early 1990s, the DOE and then the NNSA fell significantly behind schedule in conducting both laboratory and flight tests on nuclear weapons and their components (GAO 1996). Although in 1996 the DOE developed plans for conducting the delayed tests and returning to schedule, it failed to do so. By 2001, flight tests and lab tests for five of the nine weapons systems in the U.S. arsenal were significantly backlogged (DOE 2001a). Testing of several key components—the pit, the secondary, the detonator sets, and the gas transfer system—was also behind schedule.

The GAO and the DOE inspector general both found that inadequate planning for safety studies and poor coordination between testing sites were the major factors leading to the backlog. The NNSA also had difficulty coordinating flight tests with the DOD. According to the DOE inspector general:

> *When tests are delayed or are not completed, the Department [of Energy] lacks critical information on the reliability of the specific weapons involved. Additionally, anomalies or defects within the weapon systems can go undetected since the likelihood of detecting anomalies decreases when fewer tests are conducted. Without needed test data, the Department's ability to assign valid reliability levels to some weapon systems is at risk.* (DOE 2001a p. 2)

**The NNSA and the national nuclear weapons laboratories do not fully value surveillance, and ensuring that it is adequate will likely remain an uphill battle.**

The NNSA received extra funds in its FY 2001 budget to help eliminate the testing backlog. In 2006 the DOE inspector general reported that, while the agency had made some improvements, a significant backlog remained (DOE 2006a). Laboratory tests for seven of the nine weapons systems were behind schedule, as were flight tests for six. The backlog of laboratory and flight tests for five weapons systems had actually worsened. Testing of pits, secondaries, detonators, and gas transfer systems was still behind schedule.

### A Modified Surveillance Program

In 2007, the NNSA changed its procedures for surveillance testing, eliminating some of the backlog. Overall, Stage One testing was a one-size-fits-all approach to stockpile surveillance: the number of weapons tested and the types of testing were the same for every type of warhead, regardless of how many were in the stockpile or what the NNSA already knew about it. The new Stage Two testing is a more focused approach to assessing warhead reliability and safety. The NNSA determines the number of weapons to test, and the types of

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[14] Before the mid-1980s, the United States required a higher level of confidence and tested more weapons annually.

tests, by considering what it needs to know about each system and its components, testing those with a known or suspected problem more extensively.

The NNSA determines these needs and the resulting schedule annually. Warheads undergoing life extension programs—in which modifications could affect performance—receive particular attention. For example, the NNSA is testing more than 11 W76-1 warheads annually because they have seen significant changes as part of their life extension program. The stockpile also has more than enough W76-1s to allow destructive testing.

Because the active stockpile includes only a few hundred B61 bombs, in contrast, the NNSA might test only four or five each year and refrain from destroying any of the pits. Aside from the B61 and W88, the active stockpile includes a significant number of reserve warheads and bombs of other types, so their testing is not constrained by the availability of replacement weapons.

Stage Two testing is part of the NNSA's Core Surveillance Program, as was Stage One before it. The agency also began a separately funded Enhanced Surveillance Campaign in 1998, to investigate new ways to assess the aging of weapons components and materials, and to develop computer models to help predict how these components and materials will age.[15] When these new surveillance methods mature, they will become part of the Core Surveillance Program.

Under the Enhanced Surveillance Campaign, for example, the weapons laboratories developed a way to artificially accelerate the aging of plutonium samples and then measured their key properties (Heller 2010). As discussed above, these experiments led the NNSA to conclude that "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" (NNSA 2006). The experiments continue, and in December 2012 Lawrence Livermore reported that plutonium remains stable up to 150 years (Heller 2012). To allow early detection of aging, the NNSA is also conducting tests to provide a baseline for 235 components and key materials, and monitoring changes in them over time.

Despite these efforts, the NNSA's testing woes have continued under Stage Two testing. The NNSA has reduced the number of tests and weapons removed from the stockpile for testing each year (DOE 2009a). The budget for the Core Surveillance Program saw a corresponding 27 percent drop in real terms from FY 2005 to FY 2009. In a 2009 report, the JASON group observed that "the surveillance program is becoming inadequate. Continued success of stockpile stewardship requires implementation of a revised surveillance program" (JASON 2009 p. 3). The laboratory directors also expressed concern about the limited number of tests and the overall direction of the surveillance program in annual reports from FY 2006 to FY 2010. And the commander of the U.S. Strategic Command expressed concern in his FY 2009 and FY 2010 annual assessment reports (GAO 2012b).

After an internal NNSA management review in 2010 identified numerous problems with the Core Surveillance Program, the agency increased its funding by $58 million in FY 2011, which allowed a significant increase in laboratory testing (DOE 2012a). And the budget for core surveillance is slated to grow slowly to roughly $250 million over the next several years, according to the FY 2012 Stockpile Stewardship and Management Plan (Figure 2) (NNSA 2011d). To implement that plan, the agency will have to give priority to the surveillance program.

Meanwhile the Enhanced Surveillance Campaign has an annual budget of roughly $65 million (NNSA 2012b). These amounts are very modest compared with the NNSA's total annual weapons budget of more than $7 billion. There is no reason the agency cannot sustain or increase this level of support for surveillance.

After its 2010 internal review, the NNSA also created the position of senior technical advisor for surveillance, to provide greater oversight of the program. Nevertheless, problems have continued. In 2012, the GAO found that the agency had failed to establish clear measures and responsibility for implementing its own recommendations from the 2010 review and previous reviews—even though the NNSA itself had identified a lack of such metrics. According to the GAO, without a corrective action plan, "it is unclear how NNSA will (1) ensure that the draft October 2010 management review's recommendations are fully implemented and (2) demonstrate to key stakeholders, such as Congress and DOD, that NNSA is committed to improving the surveillance program" (GAO 2012b). The NNSA has said it will develop and implement a corrective action plan. The FY 2014 Stockpile Stewardship and Management Plan notes that the NNSA "instituted a new surveillance governance model in FY 2011" (NNSA 2013a p. 2-7).

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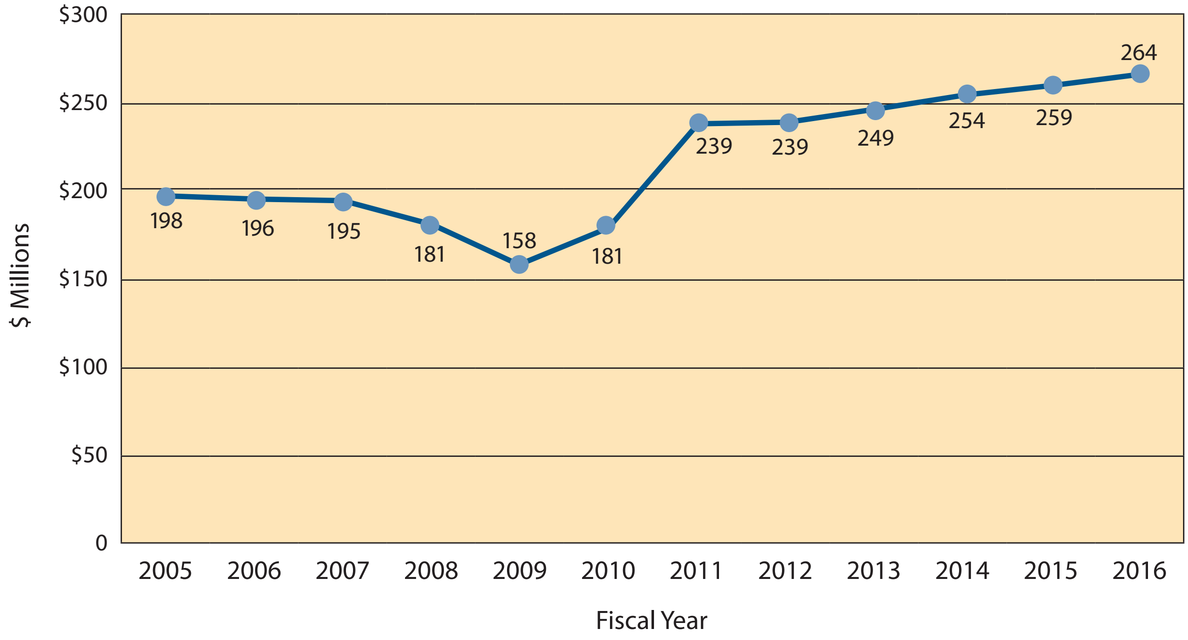
[15] The Core Surveillance Program is funded under Directed Stockpile Work, whereas the Enhanced Surveillance Campaign is funded under the Engineering Campaign.

**Figure 2. Funding for the NNSA's Core Surveillance Program**



Source: NNSA 2011d p. 61.

In another update on the surveillance program in September 2012, the agency's inspector general continued to find problems (DOE 2012a). In particular, the inspector general found that the NNSA measured the performance of the Enhanced Surveillance Program by the share of the overall budget the program spent, rather than its actual accomplishments. The NNSA has now instituted a system for measuring progress based on performance.

Despite these efforts, there are still signs that the NNSA is not giving the Stockpile Surveillance Program the priority it deserves. During a February 2013 congressional hearing, acting NNSA Administrator Neile Miller stated that the agency would preserve some program budgets under sequestration, but that the surveillance program would be among those to face cuts (Guarino 2013). And although the NNSA had originally planned to complete its baseline tests on the key components and materials of nuclear weapons by 2012, it now expects to take until 2018 (GAO 2012b).

This long history indicates that the NNSA and the national nuclear weapons laboratories do not fully value surveillance, and that ensuring it is adequate will likely remain an uphill battle. Congress will need to be vigilant in its oversight of the program.

In its FY 2013 appropriations law, Congress required a JASON review of the surveillance program, which is scheduled for completion by October 2013. Implementing recommendations from that study will be important.

## FINDING

- The NNSA has not given the Stockpile Surveillance Program the priority it deserves. Continuing on that path could lead to a lack of information on how the stockpile is aging.

## RECOMMENDATIONS

- The NNSA must give the core and enhanced surveillance programs adequate attention and funding.
- Congress must ensure that funding is adequate to support a robust surveillance program, especially in the face of budget constraints.
- Congress should monitor the NNSA's progress in developing and implementing its corrective action plan, and in completing its baseline tests for key components.
- Both the NNSA and Congress should fully consider the recommendations in the forthcoming JASON study.

## CHAPTER 4

# Stockpile Stewardship: Acquiring a Deeper Understanding of Nuclear Weapons

In response to the end of nuclear explosive testing and the ongoing cycle of development and deployment of new nuclear weapons, in 1994 the Department of Energy established the Stockpile Stewardship Program. The weapons laboratories use the program to increase fundamental scientific understanding of how nuclear weapons work.

There are two reasons the end of explosive testing might require such an understanding. First, it might help resolve a problem with a warhead that would otherwise require explosive texting. As noted, the United States pursued most of its more than 1,000 explosive nuclear tests to prove that a new weapon would work as intended, explore new weapons concepts, or assess the effects of nuclear explosions. However, the nation also occasionally used the tests to assess whether a potential problem in a weapon would degrade performance, or to verify that a modification to address a problem would result in the desired performance.

**The experimental and computational facilities needed to maintain the current arsenal may be very different from those that would be needed to implement the NNSA's "3+2" plan.**

Second, a deeper understanding would enable the labs to maintain the reliability, safety, and security of weapons as they modify them during life extension programs. With the end of the cold war, the United States stopped developing and deploying new types of nuclear weapons. While scientists did not design weapons to have a specific lifetime, they also did not specifically design them for longevity, as the nation expected to replace them regularly.

Modifications to weapons during life extension programs have been relatively minor so far, such as replacing a part with a similar one. But the NNSA is considering making more significant modifications. One purpose of the Stockpile Stewardship Program is to assess whether these modifications could degrade a weapon's performance, reliability, or safety.

As part of the program, the NNSA has invested in a range of experimental and computing facilities over the past two decades. Experiments at these facilities have allowed laboratory scientists to develop sophisticated three-dimensional computer models of nuclear weapons, which they can use to predict how a problem or a modification would affect performance, reliability, and safety.

These efforts have also led to a more detailed first-principles understanding of how nuclear weapons work. For example, a group of Livermore scientists recently solved the longstanding "energy balance" problem. Measurements during some nuclear explosive tests suggested that they had violated the law of the conservation of energy—which is not possible. Using data from modern experimental facilities as well as previous nuclear tests, scientists modeled this outcome on high-speed computers and came to understand its roots (Department of State 2012a; Hoffman 2011).

Because of the Stockpile Stewardship Program, the NNSA now believes its scientists can design and deploy new weapons without additional nuclear explosive testing. According to the NNSA's FY 2014 Stockpile Stewardship and Management Plan, "NNSA can now assess and certify integrated designs to improve safety and security without underground nuclear testing. These capabilities allow NNSA to consider a much broader range of options than previously possible" (NNSA 2013a p. 2-14).

For example, in 2006 Los Alamos and Lawrence Livermore each developed a design for the Reliable Replacement Warhead (RRW). The Livermore design was based on a previously tested weapon. The Los Alamos design, however, incorporated a primary and secondary that had been tested individually but not in the proposed configuration, yet the lab had confidence it would work. Congress cancelled the RRW program in 2008, so neither design was built.

While the NNSA is unlikely to propose building an entirely new nuclear weapon, future life extension programs could entail replacing components with those from different types of weapons or with modified components. The need for a more detailed understanding of how nuclear weapons operate, and the resulting demands on the Stockpile Stewardship Program, will therefore depend on the types of modifications made during such programs. For example, the experimental and computational facilities needed to maintain the current arsenal may be very different from those that would be needed to implement the "3+2" plan. It is important that Congress understand the indirect costs associated with aggressive life extension programs.

## Types of Experiments for Stockpile Stewardship

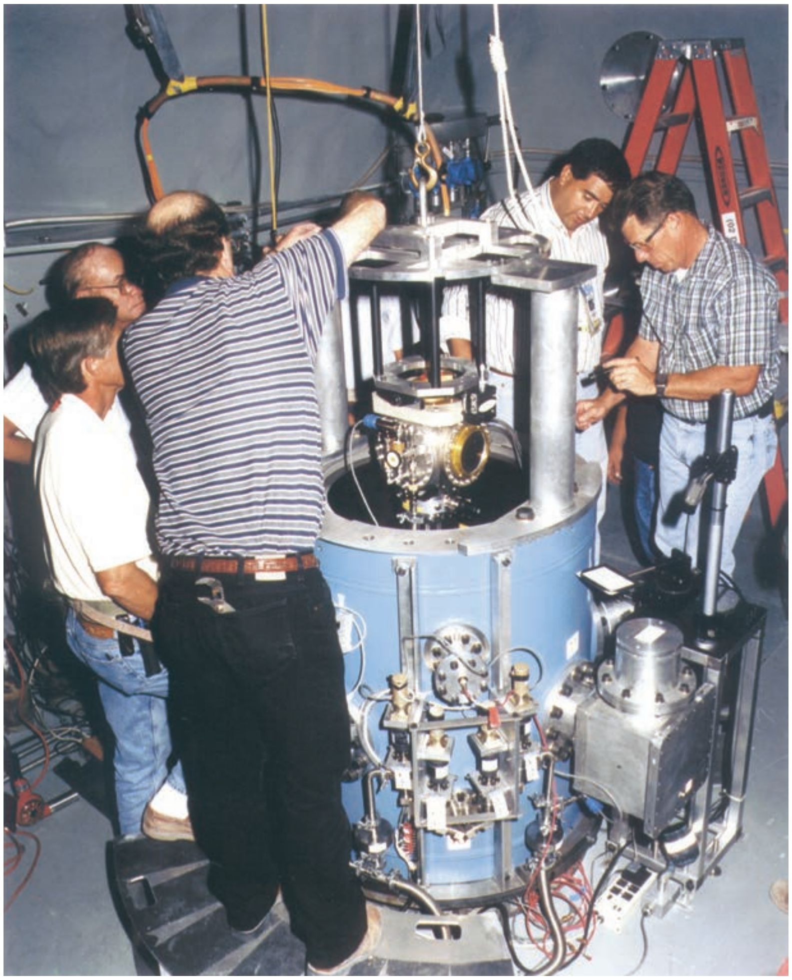
The NNSA conducts three types of experiments to increase its understanding of nuclear weapons: hydrodynamic tests, focused experiments, and subcritical tests (Table 6, p. 30).

Hydrodynamic tests are used to study the compression of the plutonium pit when the primary in a nuclear weapon implodes—the most critical step in that process. For these tests, technicians replace the pit—largely plutonium-239—with a non-fissile metal with similar properties, such as uranium-238. The other components in the primary, including the high explosive, remain unchanged. The weapon is then detonated.

Scientists use these "integrated" tests to confirm that the material behaves in the way that computer simulations predict. (The tests are called hydrodynamic because the metal flows like a liquid under high heat and pressure.) If the compression is within specifications, designers have high confidence that the rest of the weapon will work properly.

Scientists use focused experiments to measure the fundamental properties of materials, radiation, and plasmas, which they then use in computer simulations of nuclear weapons. Understanding and predicting the behavior of a material requires determining the relationships among its temperature, pressure, and density.

Scientists use subcritical tests to measure the properties of weapons-grade plutonium under high temperatures and pressures. High explosive is used to implode the plutonium—but not enough plutonium to create a chain reaction. These tests occur underground at the U1a Facility at the Nevada National Security Site.



**Workers from Lawrence Livermore National Laboratory and the Nevada Test Site lower the "cube" containing plutonium and chemical explosives into the confinement vessel to conduct a subcritical experiment, 2000.**

## Experimental Facilities

### Facilities for Hydrodynamic Tests

Scientists conduct hydrodynamic tests at three facilities: the Dual Axis Radiographic Hydrodynamic Test Facility (DARHT) at Los Alamos, the Contained Firing Facility (CFF) at Lawrence Livermore, and the Big Explosives Experimental Facility (BEEF) at the Nevada Site. The utility of hydrodynamic testing depends on the extent of changes made to the primary as part of a life extension program.

#### *Dual Axis Radiographic Hydrodynamic Test Facility*

DARHT uses X-ray radiography to produce snapshots of a mock primary as it is being explosively compressed. Two high-energy X-ray machines are oriented at 90 degrees to each other, allowing two perspectives (hence "dual axis" in the name). One machine produces a single X-ray pulse while the second produces four short X-ray pulses in rapid sequence, allowing four distinct

Photo: DOE

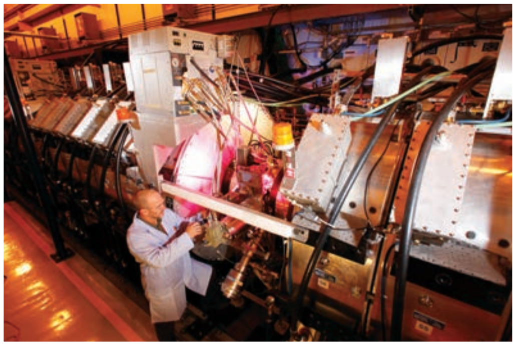
Table 6. **Facilities Used to Conduct Tests under Stockpile Stewardship**

| Facility | Location | Type of Test | FY11 tests | FY12 tests | FY13 Q1–Q3 tests |
|---|---|---|---|---|---|
| | | | Subset of tests using plutonium in parentheses | | |
| ***Hydrodynamic tests:* Integrated experiments using full-scale mockups of nuclear primaries without fissile material.** | | | | | |
| **Dual-Axis Radiographic Hydrodynamic Test Facility (DARHT)** | Los Alamos National Laboratory | Uses two X-ray machines to take snapshots of the implosion process. | 3 | 5 | 3 |
| **Contained Firing Facility (CFF)** | Lawrence Livermore Nat'l. Lab. | Uses a variety of detectors, including an X-ray machine, to measure properties of materials during test. | 7 | 3 | 6 |
| **Big Explosives Experimental Facility (BEEF)** | Nevada National Security Site | Uses high-speed optics and X-ray radiography to measure properties of materials during test. | 5 | 0 | 0 |
| ***Focused experiments:* Used to measure the fundamental properties of materials, radiation, and plasmas.** | | | | | |
| **Joint Actinide Shock Physics Experimental Research (JASPER)** | Nevada National Security Site | Uses a two-stage gas gun to determine properties of metals (including plutonium) at high shock pressures, temperatures, and strain rates. | 4 (1) | 10 (6) | 9 (4) |
| **TA-55** | Los Alamos National Laboratory | Uses a variety of platforms, including a one-stage gas gun, to determine properties of metals (including plutonium) at high shock pressures, temperatures, and strain rates. | 62 (58) | 38 (33) | 13 (5) |
| **Large Bore Powder Gun (LBPG)** | Nevada National Security Site | Will use a powder gun to determine properties of metals (including plutonium) at high shock pressures, temperatures, and strain rates (in development). | 0 | 0 | 0 |
| **Proton Radiography (pRad)*** | Los Alamos Nat'l. Lab. | Uses protons to study fundamental properties of materials. | 45 | 40 | 23 |
| **Los Alamos Neutron Science Center (LANSCE)*** | Los Alamos National Laboratory | Uses neutrons to study fundamental properties of materials. | 47 | 28 | 112 |
| **High Explosive Application Facility (HEAF)** | Lawrence Livermore Nat'l. Lab. | Uses a variety of diagnostic tools to conduct research on high explosives. | 762 | 363 | 151 |
| **National Ignition Facility (NIF)*** | Lawrence Livermore Nat'l. Lab. | Uses powerful lasers to study radiation, plasmas, and materials used in nuclear weapons. | 275 | 159 | 166 |
| **Omega*** | University of Rochester | Uses powerful lasers to study radiation, plasmas, and materials used in nuclear weapons. | 1,729 | 1,852 | 1,354 |
| **Z machine** | Sandia National Laboratories | Uses powerful X-rays to study the behavior of secondaries, plasmas, and materials used in nuclear weapons, including plutonium. | 118 (3) | 152 (3) | 112 (2) |
| ***Subcritical experiments:* Conventional explosives used to measure the basic properties of plutonium at high pressures.** | | | | | |
| **U1a Facility** | Nevada National Security Site | | 2 (2) | 1 | 1 (1) |

**NOTE:** * = national user facilities, which allocate some research time to scientists worldwide on a competitive basis.

Source: NNSA n.d. b.

The Dual Axis Radiographic Hydrodynamic Test Facility (DARHT) at Los Alamos, 1996.



Inside the Dual Axis Radiographic Hydrodynamic Test Facility (DARHT) at Los Alamos.

snapshots. Researchers use these snapshots to construct a detailed three-dimensional picture of the implosion, which allows them to observe whether it is symmetrical enough for effective detonation.

Construction on DARHT started in 1988. Initially estimated to cost $30 million, the final tally was around $300 million—a 10-fold increase. The first axis operated successfully in 1999, but the second faced repeated challenges that drove up costs. In a redesign during a pause in construction in 1995, Los Alamos officials sought to greatly improve the facility's potential by increasing its energy and adding the four-pulse capability. However, that last change made operating DARHT much more challenging. Although it was declared operational in 2003, electrical breakdowns prevented it from performing as required. After an extensive redesign and rebuild of its major components, successful simultaneous tests along both axes began in 2010.

### *Contained Firing Facility*

Scientists can use the CFF, made of reinforced concrete, to detonate up to 60 kilograms of high explosive without any appreciable release of material to the surroundings (Shang n.d.). While the CFF has several diagnostic tools, the primary one is a high-speed, high-power X-ray machine—the Flash X-Ray, or FXR, which takes snapshots of the interior of an imploding mock primary core. This machine was the forerunner of DARHT, but it is less powerful and has lower resolution. The FXR has only one beam instead of DARHT's two, so it provides a two-dimensional rather than three-dimensional image, but the FXR provides a substantially larger field of view.

CFF began operating in 2000 and remains in use, even though DARHT is up and running, according to test records in FY 2011, 2012, and the first three quarters of 2013. (The facility is also used to conduct explosives research for conventional weapons.)

### *The Big Explosives Experimental Facility*

In the early 1990s, Lawrence Livermore National Laboratory could no longer conduct large experiments on high explosive because of danger to the surrounding community, which was growing quickly. The lab successfully argued that it needed a firing facility at the Nevada Site. BEEF, created at an existing facility,

Photos: Los Alamos National Laboratory

consists of two earth-covered, steel-reinforced concrete bunkers. BEEF can handle denotations of up to 70,000 pounds of explosive, and its diagnostic equipment includes high-speed optics and X-ray radiography.

The facility began operating in 1997. It was used for only 60 tests during its first 38 months, according to the DOE inspector general, and all but three could have occurred at facilities at other sites (DOE 2001b). The inspector general recommended that the facility no longer operate full-time, and that the Nevada Site periodically review the BEEF program to determine whether further operating cutbacks were possible.

Scientists used BEEF to conduct five tests in FY 2011, but have conducted none since. The NNSA and Congress should assess whether continued operation of BEEF makes sense.

**FINDING**

- The NNSA has three facilities where scientists conduct hydrodynamic tests, and BEEF may be unnecessary.

**RECOMMENDATIONS**

- The NNSA and Congress should assess the utility of continuing to use BEEF for hydrodynamic tests.
- Congress or the administration should ask the JASON group to assess the utility of the hydrodynamic facilities for stockpile certification, under various assumptions about changes during life extension plans. The study should be unclassified, and include classified appendices as necessary.

## Facilities for Focused Experiments

The NNSA has nine key facilities where scientists conduct focused experiments. We examine six here; the other three are relatively modest in scale.

### *Shock Wave Facilities*

The NNSA uses three shock wave facilities to determine the properties of metals, including plutonium, at high shock pressures, temperatures, and strain rates (the rate at which the material deforms). These facilities are the Joint Actinide Shock Physics Experimental Research (JASPER) Facility at the Nevada Site, which is a two-stage gas gun; a one-stage gas gun at TA-55 at Los Alamos; and the Large Bore Powder Gun, in development at the Nevada Site.

In each facility, a gun is used to fire a projectile at high velocity into a target made of plutonium or other metal. The resulting shock waves shed light on the behavior of nuclear weapons, which use explosive shock waves to implode and compress plutonium to begin the nuclear reaction.

The three facilities produce different conditions with some overlap, according to the NNSA. The Large Bore Powder Gun will allow the use of larger targets than JASPER. Given budget constraints, the NNSA and Congress should carefully assess the value of the Large Bore Powder Gun before proceeding with construction.

**FINDING**

- The NNSA operates two shock wave facilities, and a third—the Large Bore Powder Gun—is in development.

**RECOMMENDATIONS**

- The NNSA and Congress should assess the utility of building the Large Bore Powder Gun, given that two similar facilities are already operating.
- Congress or the administration should ask the JASON group to assess the utility of shock wave facilities for stockpile certification, under various assumptions about changes during life extension plans. The study should be unclassified, and include classified appendices as necessary.

### *High Energy Density/Fusion Facilities*

The NNSA operates three facilities used to study materials under conditions of high energy density, and to conduct nuclear fusion experiments. These include the National Ignition Facility (NIF) at Lawrence Livermore; OMEGA at the Laboratory for Laser Energetics at the University of Rochester; and the Z machine at Sandia. The facilities use different approaches to produce fusion reactions, but they have not come close to achieving ignition: the self-sustained burning of fusion fuel.

NIF uses the world's largest bank of lasers to concentrate energy on a small sphere of heavy hydrogen isotopes, compressing and heating them until they fuse to form helium. This approach to fusion is called "inertial confinement," because the material is held together by its own inertia just long enough for the reaction to proceed.

The hydrogen is in a small cylindrical container called a hohlraum (the German word for "cavity"), which has a small hole in one end that allows laser light to enter. The laser beams are not aimed directly at the hydrogen but at the inner walls of the hohlraum, which are heated to such high temperatures that they emit

X-rays. This indirect energy in the form of X-rays—rather than the laser energy itself—compresses the hydrogen fuel. NIF uses this process, called indirect-drive fusion, to produce energy densities some 20 times greater than those at OMEGA or the Z machine.

OMEGA also uses lasers to induce inertial confinement fusion, but does not use a hohlraum. Instead, the laser energy is focused directly on the hydrogen target, in a process known as direct-drive fusion.

Like NIF, the Z machine relies on indirect-drive inertial confinement to induce fusion, but it uses intense pulsed currents rather than lasers to produce the X-rays that compress the hydrogen fuel. The X-rays are also used to determine how nuclear components and materials behave under conditions similar to those produced by nuclear weapons. Scientists can also use the Z machine to study the behavior of plutonium under conditions of high energy density.

Fusion is important during two steps in detonating a nuclear weapon: primary boosting and the secondary fuel burn. In principle, these facilities could provide some insight into both the primary and secondary fusion processes. A better understanding of boost could be needed to certify life-extended weapons that reuse primary or secondary components from other types of warheads, or that use components that have been significantly modified (JASON 2009).

All three facilities are also used for research on nuclear fusion ignition, and for fundamental science research. In 2013, the NNSA will devote 50 percent of NIF's time to stockpile stewardship, 40 percent to achieving ignition, and 10 percent to other national security missions and fundamental science. The agency will dedicate 65 percent of the Z machine's time to stockpile stewardship, 25 percent to ignition, and 10 percent to other national security missions and fundamental science. The breakdown for OMEGA will be 30 percent for stockpile stewardship, 35 percent for ignition, and 35 percent for other national security missions and fundamental science (DOE 2012e).

### *National Ignition Facility*

NIF has had a long history of technical difficulties, cost overruns, and slipped schedules since construction began in 1997. It was completed in 2009, five years behind schedule, and its final cost—almost $4 billion—was four times the initial estimate. The facility's initial operating cost was roughly $300 million a year (Broad 2012).

As its name implies, a primary goal for NIF is to achieve ignition during the fusion process. However, the NNSA failed to meet its self-imposed deadline of September 30, 2012. Moreover, in a December 2012 report to Congress, the DOE stated that "it is too early to assess whether or not ignition can be achieved at the NIF" (DOE 2012e p. v). The NNSA now plans to reassess the prospects for ignition in 2015. And in April 2013, Lawrence Livermore announced that NIF would transition to an "international science facility," thus allocating some research time to scientists worldwide on a competitive basis, and press coverage indicated that the shift would deemphasize ignition as a near-term goal (Perlman 2013).

**Ignition may be necessary but not sufficient to allow aggressive life extension options because the parameters for inertial confinement fusion differ from those important to weapons design.**

The failure to achieve ignition indicates that the computer programs developed to model inertial confinement fusion and to design the ignition targets do not incorporate all the essential factors (DOE 2012e). According to the DOE, this failure does not threaten confidence in the existing stockpile. But it may limit the changes made to weapons during life extension programs. For example, it may not be possible to have confidence in some of the modified weapons designs the NNSA is considering for the W78/W88 life extension program.

According to the GAO:

> *If ignition is achieved, experiments at NIF could be used to study the potential effects of design changes,* possibly *[emphasis added] giving NNSA greater confidence to make changes to weapons in the stockpile. But, without ignition at NIF or some other facility, NNSA's options for doing so would likely remain limited.* (GAO 2010a p. 22)

The DOE similarly noted in a December 2012 report to Congress:

> *Confidence in the present stockpile . . . is dependent upon the pedigree from a successful underground test program and a continued Stockpile Stewardship Program to understand the impact of any changes from the as-tested configuration. The gaps in understanding demonstrated by the ignition*

> *campaign are not at a level that would impact confidence in the stockpile. Rather the question is the extent to which NNSA will be able to rely upon codes and models as the basis for confidence in modifications and alterations, as NNSA extrapolates from as-tested configurations.* (DOE 2012e p. vi)

It is important to examine the claim that achieving ignition would allow validation of weapons design codes. Ignition at NIF may be necessary but not sufficient to allow aggressive life extension options, because the parameters for inertial confinement fusion differ from those important to weapons design. Moreover, some life extension options that could increase safety and security may not be viable because they are too expensive compared with the benefits, or because they would undermine confidence in the reliability of a weapon. Both reasons were apparently factors in the Nuclear Weapons Council's decision to forgo more aggressive life extension options for the B61 bomb.

**Requirements for high-performance computing will not be as great if life extension programs do not make substantial changes to nuclear warheads.**

While ignition is a key goal for NIF, the DOE argues that the facility is also valuable because experiments there "are testing codes and models that underpin stockpile confidence, are providing fundamental scientific knowledge relevant to nuclear weapons, and are attracting and retaining the scientific talent required for NNSA's broad national security missions" (DOE 2012e p. iii).

NIF can produce unmatched laser power, plasma densities, and 14-MEV (megaelectron-volt) neutron fluxes that may be useful for validating nuclear weapons codes. But NIF is not needed for stockpile certification if life extension programs do not entail major changes to weapons. As the JASON group concluded, "Lifetimes of today's nuclear warheads could be extended for decades, with no anticipated loss in confidence, by using approaches similar to those employed in LEPs [life extension programs] to date" (JASON 2009 p. 2). To assess its value, the administration should commission the JASON group to determine NIF's benefits with and without ignition, under two different assumptions: that the NNSA makes major changes to the nuclear explosive package as part of life extension programs, and that it minimizes such changes.

Increasing basic knowledge of nuclear weapons may be a goal for the scientists working on NIF. But NIF should also support the maintenance of a reliable, safe, and secure stockpile. The extent to which NIF can serve this role depends on the capabilities that it demonstrates in the future. The scientific knowledge required to fulfill that goal will depend on the changes the NNSA makes to weapons during life extension programs. Minimizing those changes might also make any basic information provided by NIF less necessary.

Because NIF is a cutting-edge scientific instrument and the goal of achieving fusion ignition is intellectually compelling, the facility has attracted top-tier scientists. The extent to which these scientists subsequently become involved in the nuclear weapons program or other national security work is unclear. Moreover, as Chapter 5 will show, the NNSA has developed a range of other programs to attract and retain qualified personnel that appear to be effective.

## FINDINGS

- The failure of NIF to achieve ignition may preclude making some types of aggressive changes to weapons as part of their life extension programs. On the other hand, even achieving ignition may not provide enough confidence in weapons design codes to allow aggressive changes to weapons.
- The utility of NIF, the Z machine, and OMEGA to the Stockpile Stewardship Program will depend on the types of life extension programs the NNSA undertakes. These facilities will be less useful if the NSSA makes only minimal changes to weapons.

## RECOMMENDATION

- The administration or Congress should ask the JASON group to assess the utility of NIF, the Z machine, and OMEGA to the Stockpile Stewardship Program. The study should consider the extent to which the facilities provide unique information relevant to stockpile certification, and the value of such information for stockpile certification under different assumptions about changes made to weapons during life extension programs. The study should be unclassified and include classified appendices as necessary.

Sequoia supercomputer at Lawrence Livermore National Laboratory, 2011.

## Computing Facilities

The nuclear weapon laboratories were among the first users of electronic computers and have remained at the forefront of computing. In May 2008, Los Alamos's Roadrunner became the first computer to attain a quadrillion ($10^{15}$) operations per second, known as a petaflop (LANL n.d. b).[16] Of course, continuing advances in computer speed mean that any ranking quickly becomes dated, and Roadrunner stood at number 22 as of November 2012 (Top 500 Supercomputer Sites 2012). The machine was decommissioned in March 2013.

The NNSA now operates two of the world's fastest computers: Cielo and Sequoia. Cielo was built at Los Alamos from 2010 to 2011, and is jointly operated by Los Alamos and Sandia (LANL n.d. a). It runs at 1.1 petaflops, and was the twenty-second-fastest computer in the world as of June 2013. Lawrence Livermore's Sequoia, completed in 2011, operates at a speed of 16.3 petaflops (LLNL 2012a). It was the world's fastest computer in June 2012, and ranked number three as of June 2013.

The DOE's Office of Science and the NNSA are now collaborating on the Exascale Computing Initiative to develop and build an exaflops computer—capable of executing a quintillion (or $10^{18}$) operations per second—by the end of this decade. The NNSA's goal is 100 exaflops, according to Dimitri Kusnezov, director of the agency's Office of Research and Development for National Security Science and Technology (DOE 2009b).

This work is occurring under the NNSA's Advanced Simulation and Computing Program, established in 1995. According to the NNSA, its hardware and software "must push the cutting edge of technology to support deterrent systems." And because "[t]echnology obsolescence for computational system hardware and software is rapid . . . [there is a] need to continually update the system in order to maintain the cutting edge" (NNSA 2011d p. 45).

As with the NNSA's other cutting-edge R&D, requirements for high-performance computing will not be as great if life extension programs do not make substantial changes to nuclear warheads. According to the Defense Science Board, the driver for the Advanced Simulation and Computing Program is "aggressive [life extension programs]. . . . The net result is a need for an increase of at least a factor of 100 in computer capability, and perhaps considerably more to respond to the long term needs of a nuclear weapons program that must make *substantial technical modifications* [emphasis added] to the existing stockpile without nuclear testing" (DOD 2009 p. 14).

On the other hand, any computer simulations are unlikely to provide enough confidence to predict the behavior of designs that are very different from those that have been previously explosively tested.

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[16] Computer speeds are measured in floating-point operations per second, or flops. A floating point is a number containing a decimal point. An operation would be addition or subtraction, for example.

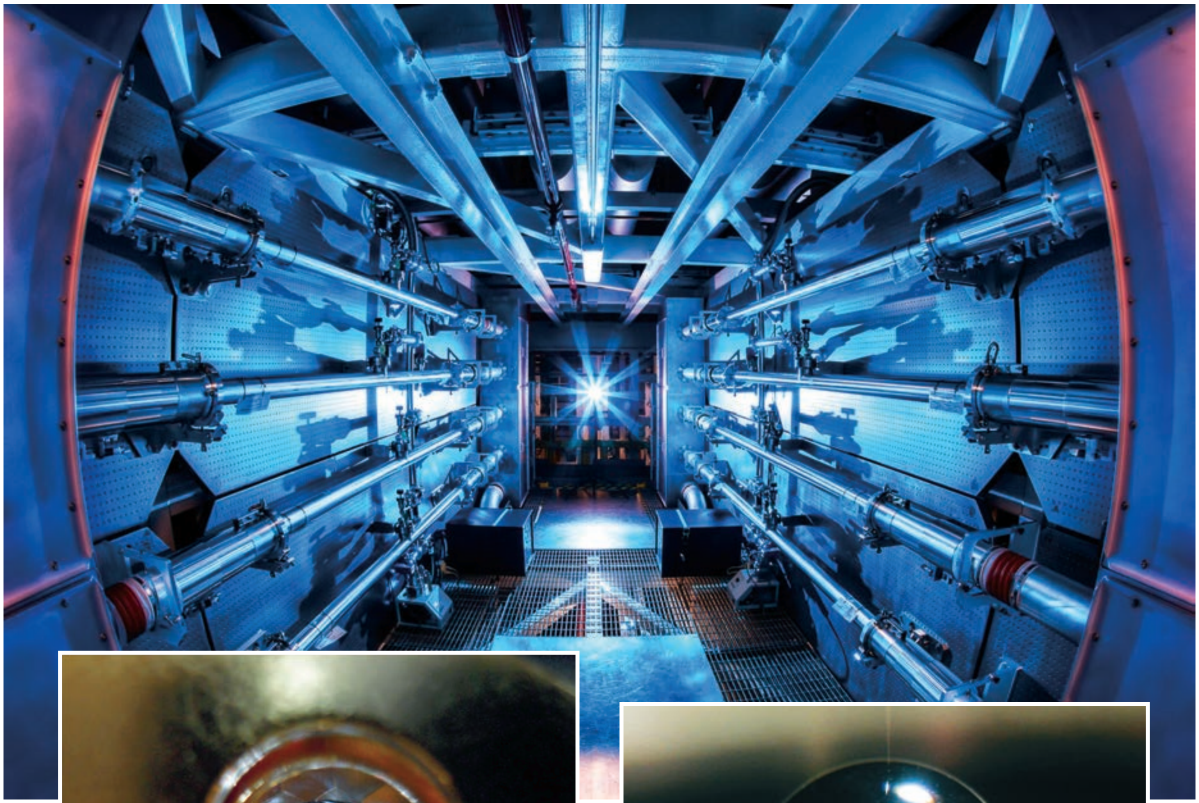
Photo: NNSA News

**FINDING**

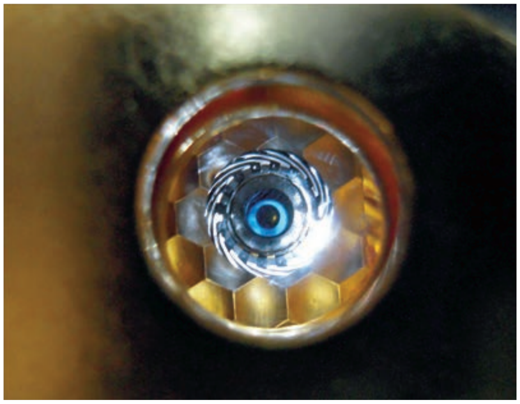
- The NNSA goal of a computing capacity of 100 exaflops assumes that life extension programs may include significant modifications to nuclear warheads. However, any computer simulations will be inadequate to allow aggressive life extension options that diverge from designs that have previously undergone nuclear explosive testing.

**RECOMMENDATION**

- The administration or Congress should ask the JASON group to study the computing capacity required to support life extension programs, using different assumptions about the changes those programs make to nuclear warheads.



A portion of the preamplifier beam transport system in the National Ignition Facility at Lawrence Livermore National Laboratory. This system transports and resizes the laser beam prior to injection in the main laser.



A view of a cryogenically cooled NIF target photographed through the hohlraum's laser entrance hole.

A two-millimeter-diameter capsule filled with a deuterium-tritium (DT) gas, surrounded by a few-nanometer-thick layer of DT ice, which is the target for the lasers of the National Ignition Facility.

Photos: (top) NNSA News; (bottom left & right) Lawrence Livermore National Laboratory

## CHAPTER 5

# Retaining a Qualified Workforce

A workforce of qualified scientists, engineers, and technicians is essential to maintaining a reliable, safe, and secure nuclear arsenal. The nation's nuclear weapons program employs roughly 20,000 people, of which some 13,000 are classified as having skills essential to maintaining the arsenal.[17] The two areas of greatest need are nuclear engineering and computer science and engineering.

After nuclear testing and the production of new types of nuclear weapons ended in the early 1990s, the DOE needed fewer employees throughout the nuclear complex, and hiring did not keep pace with retirements and other departures. After peaking in 1992 at about 50,000, employment in the nuclear weapons program had dropped to half that by 1998 (GAO 2005; Chiles Commission 1999).

### Anticipating Shortages of Key Personnel

As those cuts were occurring, members of Congress and other observers expressed concern about a potential lack of personnel with critical skills at nuclear weapons laboratories, production facilities, and test sites. Acquiring such skills typically takes several years of on-the-job training, and experts need time to pass their knowledge on to new hires before they retire. Moreover, new hires may need a year or more to obtain a security clearance.

In response, Congress established the Commission on Maintaining U.S. Nuclear Weapons Expertise in 1997—known as the Chiles Commission, after its chair, Admiral Henry G. Chiles—to review the DOE's efforts to maintain a qualified workforce. In its report, the commission found that the average age of the scientists, engineers, and technical staff had risen from 42 to 44 years at Sandia, from 44 to 46 years at Los Alamos, and from 44 to 47 years at Lawrence Livermore over the previous decade (Chiles Commission 1999). The commission also found that the average age of the technical staff was higher than the national average for such workers, but that had been the case during the cold war as well. The commission also found that the DOE, its laboratories, and its production facilities did not have a clear plan for replenishing critical personnel, and needed to expand hiring to avoid a gap in expertise.

The problem was not a national shortage of scientists and engineers but strong U.S. demand for such talent, according to the commission. The DOE and the contractors that run its nuclear weapons sites needed to find ways to recruit and retain scientists and technical specialists, such as by offering more competitive salaries and benefits. To allow contractors to be more agile in a tight labor market (most employees at the nuclear complex work for the contractors), the commission recommended that the DOE allow them to make decisions on salaries and benefits without prior approval.

After surveying some 6,000 engineers, scientists, and technicians in the complex, the commission found that the most important factors for recruiting and retaining them included not only competitive salaries and benefits but also job security, respect on the job, and interesting and challenging work. The commission found that six organizations and labs doing classified defense work outside the complex typically offered hiring bonuses, flextime, telecommuting, extra time off, educational benefits, and career counseling, and recommended that the complex follow those best practices.[18]

The commission also identified a lack of knowledge about job opportunities at the nuclear weapons complex among students at colleges that have historically supplied candidates. The intern and co-op programs offered within the complex are an effective tool to

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[17] Of course, total employment at the eight sites in the nuclear weapons complex is higher, because some employees work on environmental cleanup and other programs unrelated to nuclear weapons. Of 20,000 employees in the weapons program in 2007, 12,759 had essential skills for that program (DOD 2008). An earlier GAO report cited 10,000 critically skilled workers (GAO 2005).

[18] The six organizations were the Charles Stark Draper Laboratory in Cambridge, MA; Commonwealth Edison Co. in Chicago, IL; the Jet Propulsion Laboratory in Pasadena, CA; Johns Hopkins University Applied Physics Laboratory in Laurel, MD; Lockheed Martin in Bethesda, MD; and the Naval Research Laboratory in Washington, DC.

address that problem, according to the commission. The commission further recommended that the DOE make better use of its retired employees to help train new personnel, review work at the labs, and serve as a reserve force of experts who could be brought back should the need arise.

### Reexamining Personnel Challenges

In 2005 and 2012, the GAO reviewed the NNSA's efforts to recruit and retain key skilled personnel, as did the Defense Science Board Task Force on Nuclear Deterrence Skills in 2008 (GAO 2012a; DOD 2008; GAO 2005). The National Research Council also considered staff recruitment and turnover during an assessment of management and research at the three NNSA labs (National Research Council 2012).

**In its 2012 report, the GAO found that the restrictive work environment posed a challenge to recruiting employees to work at weapons facilities—especially younger workers.**

These reviews found that the NNSA and its contractors still face challenges in recruiting and retaining key personnel. In 2005, contractors cited four primary difficulties: the amount of time required for employees to obtain a security clearance; a shrinking pool of U.S. citizens educated in key science and technology fields; the high cost of living near some facilities, particularly the weapons labs and the Nevada Site; and the isolated location of many NNSA facilities, which limits career opportunities for spouses, among other problems.

In its 2012 report, the GAO found that the restrictive work environment also posed a challenge to recruiting employees to work at weapons facilities—especially younger workers. Much of this work must occur in secure areas without access to personal e-mail, personal cell phones, and social media, yet many young people expect to stay more or less continuously connected to their peers and family. Young candidates with the right qualifications are also often more interested in improving the environment than in designing weapons (GAO 2012a).

With fewer support staff because of budget cuts, technical personnel must now spend more time on administrative work and fund-raising and less on independent research (National Research Council 2012). An increase in DOE budget reporting categories—there are more than 100 for the nuclear weapons program at Sandia—and a trend toward funding a greater number of smaller projects has created an explosion of paperwork (NAPA 2013). Some employees also feel that their work is micromanaged (National Research Council 2012). These difficulties reflect the NNSA's larger challenge of balancing autonomy and accountability at the laboratories.

### Successful Strategies for Retaining Key Personnel

Despite these challenges, the reviews also found that the NNSA and its contractors have responded to the Chiles Commission report with strategies that have allowed them to attract and retain critically skilled employees. The 2012 NRC report found no increase in turnover among science and engineering staff at Los Alamos and Lawrence Livermore after their transition to management by private contractors in 2006 and 2007, apart from workforce cuts at Livermore (National Research Council 2012). The GAO similarly found that the average age of critically skilled NNSA employees had remained stable from 2001 to 2005, and expected it to decline beginning in 2006. (No data are readily available on whether that has occurred.)

Like the Chiles Commission, these reviews found that salary and benefits are the most important factors in retaining employees at all eight major NNSA facilities (GAO 2012a). Contractors that run those facilities have used hiring and retention bonuses—along with higher base salaries in some specialty fields—to recruit and retain skilled staff. Congressional authorization of three programs that allow the DOE to exempt up to 400 positions from normal salary caps, and the NNSA to exempt up to 300, have helped these agencies hire and retain highly skilled employees. In 2012, 430 people held such positions (GAO 2012a).

Despite the Chiles Commission's recommendation, the NNSA does not allow contractors to make their own compensation decisions: they must obtain advance approval for any changes in salaries or benefits. Even so, to enhance employee quality of life, some contractors now offer day care facilities, fitness centers, and flexible work hours. The contractors have also created or expanded professional development programs, which provide in-house training and allow employees to attend professional meetings or earn a bachelor's or advanced degree. Contractors have also created training and mentoring programs that allow experienced staff to transfer knowledge to new staff.

NNSA contractors have active recruitment programs, primarily targeting recent graduates. Internships, fellowships, and summer jobs—particularly at the nuclear weapons labs—have become a significant source of new hires. The number of postdoctoral fellows at the labs, and the quality of their work as measured by publications and citations, have risen over the past several years. Postdoctoral programs are one of the most important sources of permanent scientific and engineering staff: essentially all those hired to do basic research end up contributing to nuclear weapons projects. Some become full-time employees in the weapons program, while others continue to pursue basic research but spend part of their time on weapons projects (National Research Council 2012). To address longer-term needs and compensate for the declining number of U.S. citizens graduating with science degrees, the contractors have developed outreach programs to promote science, math, and engineering at local middle and high schools.

Like the Chiles Commission, these reviews also found that challenging, meaningful work is a significant factor in attracting and retaining key staff. NNSA contractors believe that the Stockpile Stewardship Program offers many challenges in basic research that make working at NNSA facilities attractive. The NNSA also sponsors research on arms control, nonproliferation, safeguards, counterterrorism, and counterproliferation, which adds to the intellectual challenge.

Employees at NNSA facilities also do cutting-edge work unrelated to the nuclear weapons program for other parts of the DOE. Such work accounted for about 19 percent of all work at Los Alamos, 7 percent at Lawrence Livermore, and 10 percent at Sandia in FY 2011. And under the Work for Others (WFO) program, employees at the national labs perform work for other federal agencies and nongovernmental organizations, with the DOD the largest sponsor. WFO accounted for about one-third of work at Sandia, 14 percent at Livermore, and 9 percent at Los Alamos in FY 2011 (NAPA 2013). To attract top-quality scientists and engineers, the labs must continue to develop expertise and new programs in non-nuclear areas, according to the 2012 NRC report, and all are trying to do so.

The three nuclear weapons labs are also part of the DOE's Laboratory Directed Research and Development Program, which allows them to set aside up to 8 percent of their budgets for basic non-nuclear research, awarded competitively (DOE n.d.). Overhead charged by each laboratory to both its DOE and non-DOE sponsors funds this program. Nuclear weapons production plants and the Nevada Site can also use up to 4 percent of their budgets for basic research, under the Plant Directed Research and Development and Site Directed Research and Development Programs (Table 7). None of the sites use all the budgets allotted for these programs, so they have room to expand.

The labs are also exploring other ways to expand their work and allow researchers to collaborate across the weapons complex and with colleagues in industry and academia. One example is the Livermore Valley Open Campus (LVOC), a joint effort of Lawrence Livermore and Sandia Laboratories' California site launched in 2011. Modeled after R&D campuses at major industrial parks and other DOE labs, the LVOC seeks to enhance national security by engaging with the broader scientific community (LLNL n.d.).

To make the best use of the expertise and facilities at the labs, to focus their work on the highest-priority national security needs, and to facilitate

**Table 7. Share of Total Budget Devoted to Directed R&D at Eight Nuclear Weapons Sites, FY 2012**

| | Number of projects | Directed R&D program costs (millions) | Total budget (millions) | Percent spent | Percent allowed |
|---|---|---|---|---|---|
| **Los Alamos** | 293 | $142 | $2,051 | 6.9% | 8% |
| **Lawrence Livermore** | 159 | $92 | $1,646 | 5.6% | 8% |
| **Sandia** | 433 | $162 | $2,425 | 6.7% | 8% |
| **Nevada Site** | 40 | $5.5 | $404 | 1.4% | 4% |
| **Kansas City Plant** | 102 | $12 | $634 | 1.9% | 4% |
| **Pantex** | 19 | $1.4 | $555 | 0.3% | 4% |
| **Savannah River** | 10 | $2.2 | $148 | 1.5% | 4% |
| **Y-12** | 76 | $24 | $776 | 3.1% | 4% |

Source: DOE 2013d.

long-term strategic planning, in 2010 the DOE, the DOD, the Department of Homeland Security, and the director of intelligence established an Interagency Council on the Strategic Capability of DOE National Laboratories as National Security Assets.

## The Future of the Nuclear Weapons Workforce

The NNSA and its contractors will continue to face competition in attracting highly trained technical staff. However, the strategies of offering competitive salaries and benefits and providing interesting work are likely to continue to be effective. Indeed, in the 15 years since the Chiles Commission report, retaining technical expertise has proved to be a manageable problem for the NNSA.

The economic environment has worked in the agency's favor. In a poor economy, jobs at NNSA facilities—seen as relatively stable compared with many private-sector jobs—have greater appeal, and fewer industry jobs may be available. As the economy improves, competition may grow, particularly in high-demand fields such as computer science. Salaries at NNSA facilities appear to be mid-range for comparable jobs nationwide, so the agency and its contractors may need to offer more financial incentives if the private sector begins to create more jobs (Glassdoor.com n.d.).

To help ensure that NNSA facilities remain an attractive career option for highly qualified personnel, the agency should expand the Work for Others program and opportunities for such employees to engage with colleagues outside the complex, such as the Livermore Valley Open Campus. The NNSA should also continue to support directed R&D programs, and investigate why its facilities are not making full use of the funding available to them.

### FINDING

- The NNSA and its contractors will continue to face competition in attracting and retaining highly trained technical staff. However, today's strategies of offering competitive salaries and benefits and providing interesting work are likely to overcome this challenge.

### RECOMMENDATIONS

- To make working at NNSA facilities interesting and challenging, the NNSA should expand the Work for Others program and create more innovative programs such as the Livermore Valley Open Campus.
- The NNSA should ensure that its facilities make full use of funding for directed R&D programs, which support basic research, and investigate why they are not doing so now.
- The NNSA and its contractors should continue to offer competitive salary-and-benefits packages.
- The NNSA and its contractors should provide working conditions with fewer bureaucratic constraints.

**Students in an annual summer workshop at the Livermore Valley Open Campus, 2013.**

Photo: Lawrence Livermore National Laboratory

## CHAPTER 6

# Minimizing the Security Risks of Weapons-Usable Fissile Material

The nuclear complex stores and handles large quantities of weapons-usable fissile materials—HEU and plutonium—at several sites across the United States.[19] These materials should be stored and disposed of in a way that minimizes their security risks. This chapter examines the sites in the United States that now store HEU and plutonium, considers plans to store and dispose of these materials, and suggests a more sensible path.

### Storing and Disposing of Plutonium

Since launching the nuclear weapons program during World War II, the United States has produced more than 100 metric tons of plutonium for military purposes. While some of this has been consumed in nuclear tests or discarded as waste, the U.S. inventory today exceeds 95 metric tons.[20] The federal government has declared more than 43 metric tons of this plutonium as excess to military needs, and is examining ways to dispose of it.

A simple implosion nuclear weapon requires some six kilograms of plutonium, whereas a sophisticated implosion design might use as little as two kilograms.

### Storage Sites for Military Plutonium

In recent years, the United States has consolidated plutonium at fewer sites in the nuclear weapons complex, enhancing security and reducing the costs of storing and guarding this material. About two-thirds of this plutonium—67.7 metric tons—is in pit form. Some pits are in the nuclear weapons stockpile, controlled by the DOD. The remaining pits are stored at the Pantex Plant in Texas, as either separated pits or in weapons awaiting dismantlement. Some of the pits at Pantex—23.4 metric tons' worth—are excess to military needs, while others are stored for potential reuse (Table 8, p. 42).

**Storage cask containing transuranic waste including plutonium being put on a trailer at the Waste Isolation Pilot Plant (WIPP) in New Mexico, 2002.**

Pantex is authorized to store up to 20,000 pits, and had about 14,000 as of June 2007 (*PantexInfo* 2007). Publicly announced rates for dismantling nuclear weapons suggest that the DOD added at least another 1,000 pits by the end of 2009 (DOD 2010a). A Los Alamos magazine noted in 2012 that pit storage at Pantex is "nearing capacity," but whether that means it has nearly

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[19] Highy enriched uranium consists of 20 percent or more uranium-235, while low-enriched uranium consists of less than 20 percent U-235. Weapons-grade uranium consists of more than 90 percent uranium-235. Because all HEU can be used directly to make a nuclear weapon, anything other than small amounts requires strict security measures. The Nuclear Regulatory Commission classifies amounts of fissile material in three categories, based on their potential use in nuclear weapons. Category I material is HEU containing five or more kilograms of U-235. Category II is HEU containing one or more kilograms of U-235, or LEU enriched to 10 percent or more that contains 10 or more kilograms of U-235. Category III is HEU containing 15 or more grams of U-235, LEU enriched to 10 percent or more that contains one or more kilograms of U-235, or LEU enriched to less than 10 percent that contains 10 or more kilograms of U-235.

[20] These figures do not include the 680 metric tons of plutonium in 68,000 metric tons of spent fuel from civilian reactors. Because this material is embedded in large, heavy, highly radioactive fuel rods, it is relatively invulnerable to theft.

Photo: DOE

**Table 8. Sites with Plutonium, as of September 2009 (in metric tons)**

| Facility | Plutonium not in waste | | Plutonium in waste | Notes |
|---|---|---|---|---|
| | Military + excess | Excess | | |
| **Pantex Plant** | 67.7 | 23.4 | 0 | Excess plutonium is in the form of separated pits and pits in weapons awaiting disassembly. |
| **Department of Defense** | | 0 | 0 | Plutonium under the control of the DOD is in the form of pits in deployed and reserve weapons. |
| **Savannah River Site** | 12.0 | 8.8 | 0.8 | The amount of plutonium not in waste has likely grown since 2009, as consolidation of excess non-pit plutonium from other sites was to occur through 2010. |
| **Hanford Site** | 6.6 | 0.3 | 2.1 | Plutonium remaining at Hanford is in spent fuel: four tons is in fuel from the N-reactor, and 2.6 tons is in fuel from the Fast Flux Test Facility, part of the former U.S. breeder reactor program (IPFM 2010). |
| **Idaho National Laboratory** | 4.6 | 0 | 1.4 | Idaho stored four metric tons of fresh fuel for the Zero Power Physics Reactor, retained for potential future use, as of 2007 (DOE 2007c). |
| **Los Alamos National Laboratory** | 4.0 | 1.2 | 0.6 | |
| **Nevada National Security Site** | | | 0.01 | This figure does not include plutonium contamination from nuclear tests. |
| **Oak Ridge National Laboratory** | | | 0.03 | |
| **Other sites** | 0.5 | | | As of October 2012, 0.3 metric ton of plutonium had been transferred from Livermore to Savannah River. The remaining 0.2 metric ton includes DOE-owned material in the civilian nuclear fuel cycle. |
| **Other sites** | | 0.7 | | |
| **Additional** | | 9.0 | | In 2007, the U.S. declared another nine metric tons of weapons-grade plutonium excess to military needs, and that it would be removed from retired, dismantled weapons. |
| **Waste Isolation Pilot Plant (WIPP)** | | | 4.8 | |
| **TOTAL** | 95.4 | 43.4 | 9.7 | The 43.4 metric tons of excess plutonium is weapons-grade (less than 7 percent Pu-240). There are 52 metric tons of military plutonium, of which 37.9 are weapons-grade, 12.7 are fuel-grade (7 percent to 19 percent Pu-240), and 1.4 are power-reactor-grade (19 percent or more Pu-240). |

Source: NNSA 2012f.

20,000 pits or that existing capacity is less than 20,000 pits is unclear (Dillingham 2012).[21]

In 2007, the NNSA decided to consolidate as much excess non-pit plutonium as possible—including material then at Hanford in Washington, Los Alamos, and Lawrence Livermore—at the Savannah River Site by the end of 2010 (DOE 2007c). As of September 2009, Savannah River stored 12 metric tons, of which 8.8 tons were excess, but these amounts have likely increased since then.

In September 2012, the NNSA announced it had removed all "significant" amounts of plutonium from Livermore, leaving it with fewer than 500 grams for research (NNSA 2012d). (The Nuclear Regulatory Commission classifies amounts of fissile material in three categories, based on their potential use in nuclear weapons. For plutonium, Category I, II, and III amounts are two kilograms, 500 grams, and 15 grams of Pu-239, respectively. A "significant" amount refers to Category I and II amounts of material.) Postponement of construction of the Chemistry and Metallurgy Research Replacement–Nuclear Facility at Los Alamos means that more work on characterizing plutonium will occur at Livermore. Shipments of Category III amounts of plutonium from Los Alamos to Livermore for such work are scheduled to begin in 2015 (LLNL 2013a; Dillingham 2012).

Los Alamos stored four metric tons of plutonium as of September 2009. The United States has declared 1.2 metric tons of that to be excess, and has likely moved that amount to Savannah River. The remaining 2.8 metric tons—enough for more than 1,000 pits—is available to produce new pits for nuclear warheads.

Workers at Hanford produced military plutonium for many years, and 6.6 metric tons in spent nuclear fuel remains. It is considered a low security risk, because the spent fuel is radioactive and in large and heavy fuel assemblies, making theft difficult.

Idaho National Laboratory, which conducts research on nuclear reactors and fuels, stores 4.6 metric tons of plutonium—most in fresh reactor fuel. While this fuel is not highly radioactive, the plutonium is again embedded in large and heavy assemblies, so stealing it would be difficult.

Savannah River, Hanford, Idaho, Los Alamos, and Oak Ridge National Laboratory also store material that has been contaminated with plutonium. The Nevada National Security Site (formerly the Nevada Test Site) also stores a small amount of plutonium in waste, plus unknown amounts left underground after hundreds of explosive tests.

As of 2009, some 4.8 metric tons of plutonium in waste form had been disposed of at the Waste Isolation Pilot Plant (WIPP) in New Mexico. WIPP, based in a dry rock salt bed, is a permanent repository for transuranic waste, which includes clothing, tools, rags, debris, residues, and other disposable items contaminated with plutonium and other transuranic elements. The amount of plutonium mixed in with the waste is small enough that it does not pose a security risk.

**After designating 43 metric tons of plutonium as excess to military needs, the United States now has roughly 52 metric tons of plutonium for weapons, which is enough for some 13,000 U.S. weapons—many more than needed for the current or future arsenal.**

### Plutonium Research at Lawrence Livermore

While the NNSA has removed all Category I and II quantities of plutonium from Lawrence Livermore, outside experts believe that the agency will send pits or primaries to the laboratory for periodic testing at its Hardened Engineering Test Building (Building 334) (Tri-Valley CARES 2012). This facility heats, cools, drops, and shakes components "to duplicate as nearly as possible the likely environments for a weapon during its lifetime, known as its stockpile-to-target sequence" (Sefcik 2001 p. 9). These experts expect the NNSA to grant Livermore an exemption to handle Category I amounts of plutonium on an as-needed basis. However, the site is no longer set up to handle such quantities of plutonium. According to the NNSA, Lawrence Livermore "may require special security accommodations on a periodic basis to support stockpile stewardship (NNSA 2013a p. 5–12).

Given the security risks of this plutonium, it would make more sense to move the equipment in that building to a location that already handles Category I

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[21] In 2008, the NNSA considered expanding its capacity to store pits, including by constructing a new building at Pantex. A 2008 report cited a "pinch point" between 2014 and 2022, when the number of pits stored at Pantex would exceed its capacity. However, the report also noted several alternatives to a new building, including improved storage (TechSource 2008). The fact that a Los Alamos publication says the lab is "nearing capacity" (Dillingham 2012 p. 23) suggests that a problem may still exist.

amounts of plutonium, and will continue to do so over the longer term. Pantex would be the most sensible location, because technicians there disassemble weapons from the stockpile for surveillance and testing.

**FINDING**

- The NNSA should avoid sending Category I quantities of plutonium to Lawrence Livermore, because doing so would introduce new security risks.

**RECOMMENDATION**

- The NNSA should study the feasibility of moving the equipment in the Hardened Engineering Test Building to Pantex or another site that will host plutonium over the longer term.

### Plutonium Stored at Los Alamos

The proposed Chemistry and Metallurgy Research Replacement–Nuclear Facility at Los Alamos includes a vault for long-term storage of up to six metric tons of nuclear material. In the environmental assessment conducted for the facility, the only argument made for such a vault is that the existing Chemistry and Metallurgy Research Facility has a large one. However, this is not a compelling argument. The same assessment noted that the existing vault was downgraded because of safety concerns, and contains only Category III or smaller quantities of plutonium or other radioactive materials (NNSA 2003).

Most of the plutonium at Los Alamos is stored at its Plutonium Facility. The vault there is relatively full, but waste will be processed and shipped to WIPP. If more space is needed, the "NNSA can stage plutonium for future program use in the Device Assembly Facility in Nevada," according to the agency's FY 2013 budget request (DOE 2012b p. 185).

The Device Assembly Facility was built to assemble the nuclear weapons tested underground at the Nevada Test Site. The facility was not completed until after 1992, when the United States began a moratorium on such tests. It is built to be highly secure, and is underused, relatively new, and isolated from population centers.

A 1996 DOE study identified the facility as one of several that could store plutonium pits—in this case, 8,000 (DOE 1996b). The plutonium at Los Alamos is in powdered form and easily inhaled, so it poses a greater health risk than plutonium pits (NNSA 2011c). Diverting some powder is also easier than stealing an entire pit. The NNSA may therefore need to modify the facility to allow it to store powdered plutonium safely and securely. More important, moving plutonium from Los Alamos to Nevada would undermine the goal of consolidating it and introduce new security risks, because the Nevada Site does not now store significant quantities of plutonium.

Another approach to free up space at the Los Alamos Plutonium Facility, if necessary, is to ship some material to the Savannah River Site, which already stores a large amount of non-pit plutonium.

**FINDINGS**

- The proposed vault that would be built along with the Nuclear Facility at Los Alamos is unnecessary.
- To minimize the costs and security risks of storing plutonium, the NNSA should consolidate the material at as few sites as possible.

**RECOMMENDATION**

- If some plutonium now stored at the Los Alamos Plutonium Facility must be moved to free up space, it should be transferred to the Savannah River Site.

### Disposing of Excess Plutonium

After designating 43 metric tons of plutonium as excess to military needs, the United States now has roughly 52 metric tons of plutonium for weapons. U.S. primaries contain less than four kilograms of plutonium, so 52 metric tons is enough for some 13,000 U.S. weapons—many more than needed for the current or future arsenal.

The federal government has considered two methods for disposing of excess plutonium. The first entails immobilizing it (in metal or oxide form) with highly radioactive waste in rods made of glass or ceramic material. These rods would be heavy, large, and so radioactive that theft would be very difficult. They would be disposed of in a permanent underground repository for nuclear waste, once one is built. Alternatively, the rods could be placed in very deep boreholes.

The second method entails converting suitable plutonium into an oxidized form, and then mixing it with low-enriched uranium oxide. This process produces "mixed oxide," or MOX, which could be made into fuel rods for use in commercial nuclear reactors. (U.S. commercial reactors use uranium oxide as fuel. As it burns, some is converted into plutonium, so all operating reactors already have plutonium in their core.) After use, this spent fuel would also be disposed of in a geological repository.

Although it contains plutonium and other fissionable material that could be used to make a nuclear weapon, spent fuel from commercial power plants is not attractive to terrorists because the material is in large, heavy fuel rods that remain too radioactive for direct handling for decades. Moving the rods requires heavy machinery, and extracting weapons-usable amounts of plutonium requires a major, industrial-sized program. These barriers motivated the "spent fuel standard" for plutonium disposal: The National Academy of Sciences recommended that excess plutonium from defense purposes be rendered as inaccessible and unattractive as the growing stockpile of civilian spent fuel (NAS 1994).

Both immobilization and the MOX option meet the spent fuel standard. Immobilization does so by mixing plutonium with highly radioactive material and placing it in a large, heavy object. The MOX option does so by incorporating the plutonium into fuel and irradiating it in a reactor. However, the MOX approach presents far greater security risks.

That is because fresh MOX fuel does not contain the highly radioactive components that make spent fuel dangerous and difficult to handle. Moreover, a straightforward chemical process can be used to separate the plutonium in MOX from the uranium. The manufacture, transport, and storage of MOX fuel at reactor sites would therefore increase the risk of nuclear terrorism.

Even worse, the theft of enough plutonium to build one or more nuclear weapons from a MOX fabrication facility could go undetected for several years. Such a facility would handle plutonium in solution or powder form, so measuring the exact amount in the facility would be impossible. For a facility with an annual throughput of several metric tons of plutonium, the measurement uncertainty would range from several kilograms to tens of kilograms. At a Japanese fuel production facility in the 1990s, the amount of plutonium not accounted for grew to 70 kilograms over five years.

Determining how much material remained in pipes and elsewhere required shutting down and cleaning out the entire facility. To account for that discrepancy, the Japanese operator eventually shut down the plant, and found that the missing plutonium had accumulated as dust on equipment inside. The theft of tens of kilograms—enough for several weapons—could have gone undetected for years.

Yet to cut costs and make MOX more palatable for utilities that operate nuclear power plants, the NNSA has encouraged the Nuclear Regulatory Commission (NRC) to reduce safeguards and security requirements

**MOX Fuel Fabrication Facility under construction at the Savannah River Site in South Carolina, 2012.**

Photo: NNSA News

for MOX fuel, which would otherwise need to be protected like plutonium. The NRC has already weakened security requirements for storing MOX fuel at reactor sites, and is considering across-the-board security rollbacks for MOX. Weakening security undermines a chief goal of plutonium disposition: reducing the likelihood of theft.

## U.S. Plans for Plutonium

In 2000, under Presidents Clinton and Putin, the United States and Russia each agreed to dispose of 34 metric tons of plutonium excess to military needs, using either or both approaches. Delays, disagreements, and program changes have meant that the nations have since made no progress toward that goal.

At the time, the United States planned to use both disposal methods, while Russia was intent on the MOX option. Shortly after the initial agreement, Russian officials argued that because immobilization would not change the isotopic composition of the plutonium, it would not meet the spent fuel standard. Russia threatened to withdraw from the agreement if the United States pursued immobilization. Meanwhile, the United States grew increasingly concerned about the cost of the dual-track approach. Although the DOE had concluded that immobilization would be less expensive than the MOX option, the Bush administration ended the immobilization program in 2002 and focused solely on MOX (NNSA 2002).

The U.S.-Russian agreement, updated in 2010, now specifies that both Russia and the United States will use the MOX method.[22] The United States also plans to use it to dispose of all other excess plutonium that is in a form suitable to be made into MOX. All excess plutonium that is unsuitable for conversion to MOX—roughly two metric tons—would be shipped to WIPP in southeastern New Mexico (NNSA 2012a).

The United States is building a MOX fuel fabrication facility at the Savannah River Site. The initial 2003 estimate was that construction would cost $1.6 billion and be completed by 2007. By September 2012, the total cost of the MOX program had risen to $6.8 billion, and start-up had slipped to 2016, according to press reports (Jacobson 2012). The plant's expected annual operating costs have also risen by nearly a half-billion dollars per year.

Because of these cost increases and delays, the Obama administration has decided to slow down construction of the facility and consider alternatives to MOX. In its FY 2014 budget request, the NNSA asked for $320 million to build the MOX facility—less than the $490 million budget in FY 2013 and the $450 million budget in FY 2012. Out-year funding for construction has been zeroed out. It makes no sense to continue building the MOX facility while the NNSA considers other options.

If the Obama administration decides to continue the MOX approach, the DOE needs to find one or more utilities that are willing to burn the plutonium-based fuel in their reactors. Duke Energy signed a contract to use the fuel, but allowed it to lapse in 2008. No other willing partners have emerged.

Before announcing the reconsideration, the administration's preferred solution appeared to be to have the Tennessee Valley Authority, a federally owned corporation that provides power to the Southeast, use the fuel in its nuclear reactors. The TVA is studying the idea but has not made a decision. The fuel would require extensive testing before it could be used in the TVA reactors.

## A Better Alternative

Because disposing of excess plutonium by converting it to MOX fuel poses greater security risks than immobilization, the United States should cancel the MOX program and refocus on immobilization. That would require renegotiating the 2010 plutonium agreement, but Russia would likely be willing to do so, given that the United States recently agreed to change the original agreement to accommodate Russia's desires.

Despite the $3 billion already invested in the MOX program, immobilizing excess plutonium may be less costly. It may also be possible to convert the partially completed MOX facility for use in immobilization.

How long it would take to restart the immobilization program is unclear, but continued temporary storage of excess plutonium at Savannah River and Pantex is a secure and safe option. Concerns about the vulnerability of Russian plutonium drove the relatively rapid timelines initially proposed for the program.

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[22] The 2010 update occurred in response to Russia's request to use fast breeder reactors to burn excess plutonium. Such reactors can produce more plutonium than they burn. The U.S. State Department noted that the reactors will be "operating under certain nonproliferation conditions," to ensure that they only burn plutonium and do not produce more of it (Department of State 2010).

## FINDINGS

- After disposing of excess plutonium, the United States will retain enough for some 13,000 nuclear weapons—much more than it needs.
- Disposing of excess plutonium by converting it to MOX and burning it in civilian nuclear reactors would pose greater security risks than immobilizing the plutonium.
- Continuing to build the MOX facility while considering alternatives is not a good use of funds.

## RECOMMENDATIONS

- The NNSA should declare more plutonium to be excess to its military needs.
- The NNSA should cancel the MOX program and focus on immobilizing excess plutonium.

## Storing and Disposing of HEU

As part of a weapon's secondary, HEU is a crucial component of all modern U.S. two-stage thermonuclear weapons. HEU is also used as fuel in the nuclear reactors that power all U.S. submarines and aircraft carriers. These reactors are fueled with weapons-grade HEU enriched to greater than 90 percent.[23] HEU is used in some U.S. research reactors as well, but the number is declining, as their operators are replacing HEU with fuel made of LEU, which cannot be used directly in weapons.

HEU presents a greater security risk than plutonium because it can be used to make a simple gun-type weapon, whereas a plutonium-based weapon requires a more difficult implosion design. In a gun-type weapon, conventional propellant such as smokeless powder or gunpowder slams together two subcritical pieces of HEU. Such a weapon can be made with about 50 kilograms of weapons-grade HEU, whereas an implosion-type weapon would require about 20 kilograms of weapons-grade HEU. HEU is also far less radioactive than plutonium, making it easier to handle and more difficult to detect.

While operating its nuclear weapons programs, the United States produced or acquired HEU containing about 850 metric tons of U-235. Some of this has been consumed as reactor fuel and in nuclear tests, transferred to foreign countries, or down-blended—mixed with natural or depleted uranium—to make LEU fuel for reactors. In September 2004, the date of the most recent official information, the U.S. inventory contained 687 metric tons of HEU and 547 metric tons of U-235 (DOE 2006b). As of mid-2011, the International Panel on Fissile Materials estimates that the U.S. HEU stockpile was 610 metric tons. It continues to shrink as more HEU is down-blended to LEU.

### Storing HEU

Most of the U.S. HEU inventory is stored at the Y-12 National Security Complex in Oak Ridge, TN; in weapons awaiting dismantlement or undergoing life extension at the Pantex Plant in Amarillo, TX; or in weapons at DOD sites (Table 9, p. 48). In 2004, the HEU at these sites totaled 621 metric tons—more than 90 percent of the U.S. HEU inventory at the time (DOE 2006b). This material—in warheads or a form that can easily be transported and used to make a bomb—is the most attractive to terrorists.

Other HEU, most in the form of spent nuclear reactor fuel, is stored at the Savannah River Site and the Idaho National Laboratory. Spent naval nuclear fuel is also shipped to Idaho for long-term storage or disposal. This HEU is in heavy, highly radioactive spent fuel rods that present an inherent barrier to theft.

As of 2004, almost 20 metric tons of HEU were stored at several other sites, including the three weapons laboratories, Oak Ridge and Brookhaven national

**The Highly Enriched Uranium Materials Facility at Y-12, 2012.**

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[23] Naval reactors can be converted to use LEU, and France already uses LEU to power its submarines (Ma and von Hippel 2001). However, the U.S. military has recommitted to using HEU in future boats and submarines.

Photo: Brett Pate/B&W

**Table 9. Sites Storing U.S. HEU, as of September 2004 (in metric tons)**

| Site | HEU | Form |
|---|---|---|
| Y-12, Pantex, and the DOD | 621.2 | In deployed and reserve weapons, in weapons awaiting dismantlement or undergoing life extension at Pantex, and in secondaries undergoing life extension or stored at Y-12. This material is weapons-grade HEU. |
| Idaho National Laboratory | 26.8 | Spent naval reactor fuel |
| Savannah River Site | 18.7 | HEU solution from the site's previous role as a reprocessing facility; spent fuel from foreign and domestic research reactors |
| Other sites, including Oak Ridge, Sandia, Lawrence Livermore, Los Alamos, and Brookhaven national laboratories | 19.9 | |
| **Total** | **686.6** | |

laboratories, and the Hanford Site. Some of this material has since been consolidated at Y-12, including all Category I and II HEU previously stored at Lawrence Livermore. Finally, Nuclear Fuel Services, a Babcock & Wilcox subsidiary in Erwin, TN, manufactures HEU naval reactor fuel, and stores some of it before transporting it to the Navy.

### *HEU Storage at Y-12*

The main repository for weapons-related HEU is a new facility at Y-12, the Highly Enriched Uranium Materials Facility. This high-security facility, which replaced several aging structures at Y-12 and across the country, stores HEU from throughout the nation's nuclear complex. Often touted as the Fort Knox of HEU, the facility is made of reinforced concrete and designed to withstand various kinds of disasters, including flooding, earthquakes, lightning strikes, tornadoes, and aircraft impact (DOE 2013b). Construction was begun in 2004 and completed in 2008 at a cost of $550 million. The facility began operating in 2010, and is planned for a lifetime of 50 years.

The transfer of HEU from several other locations at Y-12 to the new facility was completed in August 2011, and about 68 percent of Y-12's HEU is now stored there (NNSA 2011e). The other 32 percent is in use elsewhere at the site to supply near-term needs. Shipments of HEU from other sites will go directly to the facility.

As Chapter 2 noted, the NNSA also plans to build the Uranium Processing Facility at Y-12 to further consolidate facilities that handle significant amounts of HEU. According to the agency, that facility will allow a 90 percent reduction—from 150 to 15 acres—in the site's "protected area," which requires the highest level of security (B&W Y-12 2011).

While consolidation of HEU in the Highly Enriched Uranium Materials Facility is intended to improve security, a recent event raised questions about protection at Y-12. On July 28, 2012, three antinuclear protestors—an 82-year-old nun and two middle-aged men—used bolt cutters to slip through fences and entered the protected area surrounding the facility, the highest-security area at Y-12. Although their intrusion set off several alarms, the three were in the secured area long enough to put up banners and paint slogans on the outside of the building before being apprehended by Y-12 security forces. While the three did not enter the building, their ability to reach it could have had serious consequences if they had been terrorists.

After investigating the incident, the DOE inspector general found that multiple security measures, including video cameras, were not active at the time of the break-in, and that security personnel did not respond to several alarms that did function—partly because of many past false alarms. One press report cited up to 200 false alarms per day, many triggered by squirrels and other small wildlife (Priest 2012). Another cited 800 false alarms in just the four days leading up to the break-in (Munger 2013). The investigation also found that personnel inside the facility did not react to the noise the protestors made while using hammers to hang banners outside because maintenance workers had often arrived without advance notice (DOE 2012d).

While investigators studied the break-in, the NNSA suspended all nuclear operations at Y-12 and placed all enriched uranium in vaults for two and a half weeks. One member of the Y-12 security force was fired, several others were disciplined, and all site employees attended security training. The NNSA also removed top officials at the site's management contractor, Babcock & Wilcox Y-12, and its security contractor, WSI–Oak Ridge, and issued a "show cause" notice to B&W Y-12, giving it 30 days to explain why its contract should not be revoked. WSI–Oak Ridge, which had received a citation for exemplary performance just one month before the break-in, was ultimately fired as security contractor (Schelzig 2012).

### *HEU Storage at Savannah River*

The 2004 U.S. inventory of fissile materials listed 18.7 metric tons of HEU stored in the L-Area Complex at Savannah River (SRNS 2011; DOE 2006b). This HEU is in multiple forms, including spent nuclear fuel from foreign and domestic research reactors.

### *HEU Storage at Idaho*

While not part of the nuclear weapons complex, Idaho National Laboratory also houses a significant amount of HEU in its Naval Reactors Facility. In 2004, Idaho stored some 27 metric tons of HEU in spent naval reactor fuel. The Navy projects that a total of 65 metric tons of HEU in spent fuel will be sent to the facility by 2035, when its agreement with the lab expires (BRC 2012). The NNSA has no plans to reprocess this spent fuel; it will be stored until it can be disposed of in a geological repository (GAO 2011a).

This fuel is placed in pools until it has cooled enough for transfer to canisters designed for both dry storage at Idaho and later transport and disposal (BRC 2012). Because the HEU is in highly radioactive spent fuel, it is a less attractive target for terrorists than the material at Y-12 and Pantex.

## Disposing of Excess HEU

In 1994, the United States declared 174 metric tons of HEU to be excess to military needs. Of this, 18 metric tons were in the form of waste, and the remaining 156 metric tons were to be down-blended to LEU and used to make reactor fuel.

In 2005, the United States withdrew another 200 metric tons of HEU from use in nuclear weapons, setting aside 160 metric tons of that for use as fuel in naval nuclear reactors. (The NNSA supplies 3.7 metric tons of HEU to the Navy each year, and must provide

**After planned down-blending is complete, the United States will retain about 260 metric tons of HEU for weapons purposes, which is enough for 10,000 to 16,000 U.S. weapons—or two to three times the size of the current arsenal.**

**Graffiti and blood on the Highly Enriched Uranium Materials Facility left by trespassers during the Y-12 break-in, 2012.**

Photo: U.S. government photo courtesy of Transform Now Ploughshares

Table 10. **Status of Excess U.S. HEU**

| | Metric tons of HEU | Notes |
|---|---|---|
| **Declared excess to military needs** | 174 | In 1994 |
| **Withdrawn from use in nuclear weapons** | 200 | In 2005 |
| **Total** | 374 | |
| **Reserved for naval fuel** | 128 | 160 metric tons were originally set aside from the 2005 declaration, but 32 metric tons of this are anticipated to be unusable for naval fuel and will be down-blended. |
| **Reserved for space and research reactor fuel** | 20 | Set aside from the 2005 declaration. |
| **To be down-blended by 2050** | 208 | Another nine metric tons of HEU in irradiated fuel from research reactors will be down-blended, for a total of 217 metric tons. About 130 metric tons have already been down-blended. |
| **Waste** | 18 | From 1994 declaration amount |

HEU through 2050, under an agreement with the DOD.) The NNSA anticipates that 32 of the 160 metric tons will be unsuitable for naval fuel, and will instead be down-blended (NNSA 2011a).[24] Another 20 metric tons of HEU were reserved for space and research reactors that now use HEU, and the remaining 20 metric tons will be down-blended (DOE 2005). Thus, of the 374 metric tons of HEU that the United States has declared to be excess to nuclear weapons, it expects to down-blend 208 metric tons (Table 10).

**Weapons are dismantled at a lower rate than in the past, and that slowdown also means a slowdown in disposing of HEU.**

Nine metric tons of HEU from spent fuel from U.S. and foreign research reactors are also slated to be down-blended. Thus, the DOE's Surplus Fissile Materials Disposition Program aims to down-blend a total of 217 metric tons of HEU by 2050 (GAO 2011b). After this down-blending is complete, the United States will retain about 260 metric tons of HEU (containing 230 metric tons of U-235, for an average enrichment level of 88 percent) in weapons and for weapons purposes, and another 130 tons of weapons-grade HEU for naval reactor fuel (IPFM 2010).

U.S. weapons contain roughly 15 kilograms of weapons-grade HEU in the secondaries, and some weapons also contain about 10 kilograms of HEU in the primary. If each weapon contains 15 to 25 kilograms of HEU enriched to 95 percent U-235, the 260 metric tons of HEU is enough for 10,000 to 16,000 weapons—which is two to three times the size of the current arsenal.

As of January 2012, 128 metric tons of surplus HEU had been down-blended, and another 11 metric tons had been delivered to commercial facilities for near-term down-blending (State Department 2012b). The resulting LEU, used for fuel for research and power reactors, has an estimated market value of several billion dollars (Person, Davis, and Schmidt 2012). Meeting the DOE's goal would require down-blending another 80 metric tons by 2050, or just two metric tons per year—much lower than previous rates of up to 20 metric tons per year.

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[24] As of July 2012, about eight metric tons from the naval fuel allotment had been returned as unsuitable (Person, Davis, and Schmidt 2012).

NNSA officials acknowledge that the 2050 target date is an arbitrary placeholder, and that down-blending could be completed earlier. The reason for choosing a date so far in the future, according to the agency, is that the actual rate of down-blending depends on when the HEU—some of which will come from dismantled retired weapons—is received. All dismantling of weapons now occurs at the Pantex Plant, where this operation competes for space and personnel with life extension programs. As a result, weapons are dismantled at a lower rate than in the past, and that slowdown also means a slowdown in disposing of HEU (GAO 2011b).

## FINDINGS

- The NNSA's deadline of 2050 for disposing of excess HEU is arbitrary, and disposal could be completed much sooner.
- After disposing of excess HEU, the United States will retain enough HEU for 10,000 to 16,000 nuclear weapons—much more than is needed for the current and future arsenal.
- Building the new Uranium Processing Facility would allow greater consolidation of the HEU in use at Y-12.

## RECOMMENDATIONS

- The NNSA should speed up the down-blending of existing excess HEU. Some of the resulting LEU should be reserved for use in commercial reactors to produce tritium.

**Workers take highly enriched uranium acquired from Russian nuclear weapons and convert it into low-enriched uranium for use in U.S. commercial nuclear reactors, 2004.**

- The NNSA should declare more HEU to be excess to military needs, and dispose of it expeditiously through down-blending or direct disposal.
- The NNSA should remove any remaining Category I HEU at weapons labs and other sites, and consolidate it at Y-12.
- The NNSA should construct the Uranium Processing Facility after assessing the need for production of new secondaries (see Chapter 2).

Photo: DOE

CHAPTER 7

# Dismantling Nuclear Warheads and Verifying Nuclear Reductions

The Obama administration's Nuclear Posture Review notes the need for "a comprehensive national research and development program to support continued progress toward a world free of nuclear weapons, including expanded work on verification technologies and the development of transparency measures" (DOD 2010b p. vii). Thus, beyond maintaining the nuclear arsenal, the nuclear weapons complex also requires the capability to dismantle retired weapons in a timely fashion, and to develop ways to verify reductions and disarmament.

## Dismantling Nuclear Warheads

The DOE defines dismantlement as the separation of a weapon's fissile material from its high explosive components (DOE 1997). Before that can occur, the nuclear explosive package (or "physics package"), which contains both the fissile material and high explosive, is removed from the weapon's casing. This step—known as mechanical disassembly—also includes removing other non-nuclear components. Once mechanical disassembly is complete, the weapon's physics package is disassembled, with the high explosive, secondary, and pit stored or disposed of separately.

U.S. nuclear weapons are dismantled in specialized protective facilities called bays and cells at the Pantex Plant. Weapons that use insensitive high explosive are disassembled in bays, which are more numerous but less protective than cells. The physics package is then moved to a cell, where the pit and secondary are separated from high explosive and other components. For weapons that do not use insensitive high explosive, the

Workers dismantle a B53 nuclear bomb at the Pantex plant, 2007.

Photo: NNSA News

**As part of the dismantlement of warheads at the Pantex plant in Texas, copper, aluminum, silver, gold, plutonium, and non-nuclear weapons parts are separated for recycling, 1992.**

entire dismantlement process occurs in cells, which provide the highest level of safety.

Pits from dismantled weapons are placed in storage at Pantex, while secondaries are sent to Y-12 for storage or further disassembly and disposal of the HEU and other components. Non-nuclear components are either reused or disposed of according to their specific requirements. High explosive, for example, is burned at Pantex. The cells and bays at Pantex are also used for other operations, including the assembly and disassembly of weapons undergoing surveillance or being upgraded as part of a life extension program. These missions compete for limited space and staff time with the dismantlement mission.

The only other location in the U.S. nuclear complex that can dismantle nuclear weapons is the Device Assembly Facility at the Nevada Nuclear Security Site (NNSS), originally built to assemble weapons for underground testing. Like Pantex, this facility has both bays and cells that can be used to disassemble weapons, including those that contain conventional rather than insensitive high explosive. However, the facility is smaller, with five cells and seven bays, compared with 13 cells and 60 bays at Pantex. Pits would have to be shipped to Pantex for storage, posing more security risks.

The United States has made major cuts in its deployed and reserve stockpiles of nuclear weapons in the past few decades, and now has a backlog of weapons waiting to be dismantled. In 2008, the NNSA stated that it would dismantle all nuclear weapons retired before FY 2009 by the end of FY 2022, and has developed directives to align planned and projected work rates at Pantex and Y-12 with this goal (DOE 2013a).

A recent review of the NNSA's weapons dismantlement and disposition program by the DOE inspector general found that the agency had met or exceeded its goals for FY 2010 and FY 2011 (DOE 2013a).[25] However, the report expressed concern that safety and security challenges with the aging infrastructure at Pantex could undermine its ability to fulfill dismantlement and other missions. Pantex is behind schedule on its FY 2013 work in all areas, including dismantlement, production, and surveillance, because of unexpected downtime for maintenance (Jacobson 2013c).

The NNSA requested $51.3 million for dismantlement work in FY 2013, slightly less than its requests of $56.6 million and $58 million in FY 2012 and FY 2011, respectively. The agency indicated that it planned to request a similar level of funding in upcoming years (DOE 2011a). The planned work does not include dismantling weapons retired after FY 2009, including those removed under New START. Dismantling these weapons—as well as those subject to any follow-on agreement with Russia—would not begin until

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[25] The NNSA does not make public the exact number of weapons it dismantles each year, citing security concerns.

Photo: DOE

FY 2023. The NNSA says that weapons not retired by FY 2009 will be dismantled by FY 2038, and that based on current warhead numbers it will have the capacity to meet this schedule (DOE 2013b p. 1-5). It is not clear how the schedule would be affected if the United States makes further reductions in its arsenal.

While existing U.S.-Russian arms agreements cover only deployed arsenals, future bilateral and multilateral agreements will likely cover reserve weapons as well. In that case, dismantling weapons in a timely manner—rather than allowing a 10- to 15-year lag—will become more important.

### FINDINGS

- Dismantlement of retired warheads competes for space with surveillance and life extension programs at Pantex.
- If future arms agreements cover reserve weapons, the dismantlement capacity at Pantex may be inadequate.

### RECOMMENDATION

- When planning life extension programs, the NNSA should account for the need to dismantle all retired weapons in a timely manner.

## Verifying Reductions in Nuclear Warheads

As the United States and Russia reduce their arsenals below the New START level of 1,550 deployed warheads, they will likely reach a point where verifying the number of delivery systems will no longer suffice, and they will want warhead-level verification. Agreements with other nuclear weapon states will also likely require verification of warheads as well as delivery systems.

Verifying warheads poses greater technical challenges than verifying delivery systems. Because warheads are smaller and more easily concealed, "national technical means"—that is, remote surveillance—will not suffice. Instead, verification may need to be relatively intrusive, and some verification techniques may be less acceptable to participating nations. The inspecting country or organization will want to determine whether an object to be dismantled is, in fact, a warhead, as well as the amount of fissile material it contains and whether that material has been accounted for and secured at the end of the process.

Because the designs of a nation's nuclear weapons are highly classified, and access to such information could allow other nations to develop or improve their own weapons, verification cannot reveal such sensitive information. Devising an acceptable verification regime at the warhead level will therefore be difficult.

Analysts have suggested many technological solutions to these challenges, including tags and seals to aid in detecting whether items have been tampered with or removed during dismantlement, and "information barriers" to allow inspectors to confirm that an item is the correct type of warhead without observing it directly. More work is needed to move these ideas and demonstration projects to workable systems.

Dedicated facilities could ease the monitoring and verifying of the dismantlement process. A nation with such a facility would not have to give inspectors access to a facility where other sensitive operations also occur. The design of a dedicated facility could also ease monitoring. Giving inspectors information about that design would allow them to better plan their work and bolster confidence that they could detect deception. Some experts have suggested building identical facilities in the United States and Russia designed to make the process as transparent as possible without revealing sensitive information. Such facilities could have limited access points, and technologies such as closed-circuit television (Doyle and Meek 2009).

### U.S. Research on Verification

The United States began investigating techniques to solve the technical challenges of warhead-level verification as early as 1967, and pursued ever more detailed research—sometimes with the Soviet Union/Russia—through the 1990s. These efforts culminated in the Trilateral Initiative of the United States, Russia, and the International Atomic Energy Agency (IAEA) (Cliff, Elbahtimy, and Persbo 2010). This initiative, which ran from 1996 to 2002, aimed to create a system through which nations with nuclear weapons could submit excess fissile material to the IAEA for monitoring, to prevent reuse or diversion. This work focused on three areas: authenticating warheads, monitoring inventory, and verifying the conversion of fissile material from weapons to non-weapons forms.

The United States has since moved away from taking a lead role in research on verification, leaving other nations to explore avenues for further progress. One such effort, the UK-Norway Initiative, began in 2007 and is a collaboration with the Verification Research, Training and Information Centre (VERTIC), a nongovernmental organization. Through meetings and exercises, the parties investigate new verification techniques and seek to encourage nations with and without nuclear weapons to collaborate on arms control.

All three U.S. nuclear weapons labs pursue some technical research on arms control and nonproliferation. In addition, the Cooperative Monitoring Center at Sandia, created in 1994, provides "a forum for technical and policy experts from around the world to explore how unclassified, shareable technology could help implement confidence building measures (CBMs), treaties or other agreements" (SNL n.d.). What fraction of their work the labs devote to verifying future arms cuts—and in particular, warhead-level verification—is unclear, because the NNSA's budget request does not disclose such details. According to an FY 2011 annual report from the NNSA's Office of Nonproliferation and International Security, the office directed about $38 million of its $149 million budget to nuclear verification. Of that, about $18 million was dedicated to dismantling warheads and making the disposition of fissile material transparent (NNSA 2012e). In FY 2012, the program received about $154 million in funding, with about $40 million of that going to nuclear verification (NNSA 2013b). The FY 2012 report, however, does not break down these numbers any further, so it is not possible to determine how much was devoted to verifying warhead dismantlement.

In 2010, the NNSA also established a new National Center for Nuclear Security, "to enhance the Nation's verification and detection capabilities in support of nuclear arms control and nonproliferation through R&D activities at the NNSS" (Chipman, Klingensmith, and Snelson 2012). Work at the center focuses on technologies for verifying treaties and controlling the spread of nuclear weapons, and on nuclear forensics to determine the source of the fissile material used in a terrorist weapon. Again, what part of the center's work—if any—is devoted to verifying arms reductions is unclear.

The NNSA has also proposed creating an International Center for Arms Control and Verification Technology, "to integrate the development, testing, and validation of technologies applied to control the spread of weapons of mass destruction" (DOE 2012c p. 5-10). The center would promote collaboration among U.S. agencies and international partners, and host exercises in on-site inspection and joint field training. The center would also have facilities for training IAEA and Comprehensive Nuclear Test Ban Treaty inspectors. Given budget concerns, where this proposal now stands is unclear. But its mission is nonproliferation, not arms reduction.

Funding and staffing for research on verifying arms reductions appears to have declined. A 2009 report by two Los Alamos researchers notes that "over the past decade there has been an erosion of the technical and institutional base for verified nuclear arms reductions. This is a key issue with respect to the national labs and other DOE facilities" (Doyle and Meek 2009 p. 6).

Part of this drop may stem from a series of reorganizations that have diluted the mission of verification programs. At Livermore, for example, the Nonproliferation, Arms Control and International Security Directorate was renamed the Nonproliferation, Homeland, and International Security Directorate, and reorganized to emphasize homeland security after 9/11, with a new division to counter chemical and biological attacks (Wampler 2006). In 2007, the program was again renamed, this time as the Global Security Directorate, and its mission expanded still further to include energy and environmental security. The directorate is now divided into four main divisions: chemical/biological/explosives security and infrastructure protection, energy security and nonproliferation, intelligence programs, and nuclear counterterrorism (LLNL 2013b). The addition of the homeland security and energy security missions without a corresponding increase in funding or staff means that work on monitoring and verifying arms control efforts has declined.

National security includes the ability to achieve verifiable reductions in nuclear weapons by other nations. To meet these security needs and fulfill its long-term commitment to eliminate nuclear weapons, the United States will want to understand the trade-offs involved in technologies and strategies to verify further reductions and steps toward disarmament. The NNSA should ramp up its research on warhead-level verification, and the United States should seek to resume its collaborative verification work with Russia, and to include other nations in this effort. Without adequate research on verification, the United States could compromise its ability to move forward with treaties that would make it more secure.

## FINDINGS

- Funding and support for research on verifying nuclear arms reductions has declined over the past decade.
- Future reductions in U.S. and Russian nuclear stockpiles, and the inclusion of other nations in this process, may require new warhead-level verification techniques.
- As the United States further reduces its nuclear arsenal, it will need to develop the technology and expertise to support such reductions.

## RECOMMENDATION

- The NNSA should increase funding for research on verifying nuclear arms reductions and disarmament, including at the warhead level.

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APPENDIX

# The Nuclear Weapons Complex

The U.S. nuclear weapons complex is the set of facilities that researches, designs, produces, maintains, and dismantles the country's nuclear weapons. These eight facilities include the three national security laboratories (historically called weapons laboratories): Los Alamos National Laboratory, Lawrence Livermore National Laboratory, and Sandia National Laboratories. The facilities also include four production sites—the Kansas City Plant, the Pantex Plant, the Savannah River Site, and the Y-12 National Security Complex—and one test site: the Nevada National Security Site (formerly known as the Nevada Test Site).

**While the United States has not produced new nuclear weapons or carried out a nuclear explosive test since the end of the cold war, the sites belonging to the complex still have a major role to play in maintaining the arsenal.**

While the United States has not produced new nuclear weapons or carried out a nuclear explosive test since the end of the cold war, the sites belonging to the complex still have a major role to play in maintaining the arsenal. The laboratories are responsible for research related to evaluating and maintaining existing weapons, such as studying how the materials used in nuclear weapons age. The labs use this information to develop plans for extending the life of the arsenal, as well as to inform the Annual Stockpile Assessment, a yearly report required by Congress certifying that the U.S. nuclear stockpile remains safe, secure, and reliable. The labs also undertake research related to nuclear nonproliferation, counterterrorism, and verification of arms control agreements.

The four production sites still produce and assemble materials and components for nuclear weapons. Some weapon components must be replaced on a regular basis as long as the weapons remain in the stockpile. Others are produced on an as-needed basis, as part of programs to extend the life of the nuclear arsenal. So far, these life extension programs have simply refurbished existing weapons, but in the future could entail modifying the weapons or replacing them with different, newly built ones.

The Pantex Plant and Y-12 are also responsible for dismantling retired weapons, and store most of the U.S. stock of plutonium and highly enriched uranium outside of weapons, respectively.

The Nevada National Security Site no longer conducts nuclear explosive tests, but still maintains several facilities needed for other types of testing critical to the Stockpile Stewardship Program. It also remains under a presidential directive to maintain the capability to restart nuclear explosive testing within two to three years if directed to do so.

The complex is administered by the National Nuclear Security Administration (NNSA), a semiautonomous agency within the Department of Energy (DOE), and is directly managed by private contractors that oversee each site. The complex had an overall budget of about $11.5 billion in FY 2013. While the NNSA has renamed the complex the Nuclear Security Enterprise to reflect a broadening of its mission, the bulk of the work done at the sites is still devoted to nuclear weapons, and nearly 70 percent of its overall budget is allocated directly to weapons activities.

Many of the sites within the complex date back to the early cold war, or even the original Manhattan Project, and some buildings and facilities are reaching or past their intended life spans. As the United States makes decisions about the future of its nuclear arsenal, it must also make corresponding decisions about the future of these facilities, and the long-term capabilities the nation needs.

This appendix provides background information on each of the sites in the complex, including basic information on their history, mission, and budget, to give an overview of their role in maintaining the U.S. nuclear stockpile.

# KANSAS CITY PLANT

The Kansas City Plant (KCP) produces or procures about 85 percent of the non-nuclear components for U.S. nuclear weapons. The remaining components are produced at Sandia National Laboratory. The site, which dates to 1943, originally assembled aircraft engines for Navy fighters during World War II, but in 1949 the facility was taken over by Bendix Corporation and began producing non-nuclear components for the Atomic Energy Commission.

The KCP is currently in the midst of a move from its original location at the larger Bannister Federal Complex, in Kansas City, MO, to the new National Security Campus about eight miles south. The NNSA decided to build the new site because of aging facilities and increasing maintenance and operations costs at the old site. Construction on the National Security Campus was completed in late 2012, and the initial transfer of workers and equipment began in late January 2013. The original facility will continue to operate through FY 2014, when the transfer of all NNSA-related production will be complete.

The KCP also has satellite operations in New Mexico and Arkansas to support other DOE organizations involved in nuclear weapons activities.

## The KCP Today

With the end of the cold war and a 1992 moratorium on nuclear explosive testing, the KCP's mission shifted from producing parts for new nuclear weapons to supplying new components for existing weapons in support of the Stockpile Stewardship Program. The KCP produces or procures more than 100,000 parts annually, including a wide range of mechanical, electronic, electromechanical, metal, and plastic components. It is also responsible for testing and evaluating the parts it produces.

In addition, the KCP participates in limited-lifetime component exchanges for stockpile weapons. No special nuclear material (i.e., weapons-usable plutonium or highly enriched uranium) is kept on site.

The KCP is operated by Honeywell Federal Manufacturing and Technologies. It employs a total of about 2,500 workers across its locations, with about 2,300 of those at its Kansas City site.

Kansas City Plant, 2012

## Budget

The KCP's total FY 2013[1] funding from the DOE is $535 million, of which nearly all ($532 million) is for weapons activities. Within that category, the largest amount ($234 million) is for directed stockpile work, which includes evaluation, maintenance, and refurbishment of the nuclear stockpile. An additional $183 million in weapons activities funding is designated for readiness in technical base and facilities (that is, operation and maintenance of NNSA program facilities). The remaining funds outside the weapons activities category are largely for defense nuclear nonproliferation ($2.7 million).

For FY 2014 the KCP requested a total of $579 million, with nearly all ($562 million) of this total for weapons activities. The KCP's FY 2014 request for defense nuclear nonproliferation funding increased to $17 million. Rather than indicating increased work in this area, however, this is due to a reorganization of the NNSA budget that shifted funding for two nuclear counterterrorism and counterproliferation programs from the weapons account to defense nuclear nonproliferation. The jump in requested funding for site stewardship from $2 million in FY 2013 to $180 million in FY 2014 also reflects a change in NNSA budgeting categories.

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[1] Numbers for FY 2013 are based on the Continuing Resolution annualized for the full year.

Photo: NNSA News

# LAWRENCE LIVERMORE NATIONAL LABORATORY

The Lawrence Livermore National Laboratory (LLNL), established in 1952 as the Lawrence Radiation Laboratory, was a spinoff of the University of California Radiation Laboratory at Berkeley. Arising from work by physicists Edward Teller and Ernest O. Lawrence, the lab was created to aid the United States in the research and development of nuclear weapons, in part by competing with Los Alamos National Laboratory. LLNL designed the first nuclear warhead for a U.S. submarine-launched ballistic missile and the first warheads for multiple independently targeted reentry vehicles (MIRVs).[2]

Today, LLNL is one of three privately managed DOE facilities that conduct research and design on the U.S. nuclear weapons stockpile, along with Los Alamos National Laboratory and Sandia National Laboratories.

LLNL's main site in Livermore, CA, is about 50 miles east of San Francisco. A second site—Site 300, used for experimental tests—is between Livermore and Tracy, CA.

## Lawrence Livermore Today

When the United States ended nuclear explosive testing in 1992, LLNL's primary mission shifted to stockpile stewardship. LLNL conducts life extension programs (LEPs) on existing weapons, which involves replacing components affected by aging with newly manufactured and sometimes modernized components. Under current NNSA plans, future LEPs will entail replacing existing warheads with new ones.

In support of congressional requirements for an annual report certifying the safety, security, and reliability

**Lawrence Livermore National Laboratory, 2011**

Photo: NNSA News

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[2] MIRVs allow a single missile to carry multiple warheads that can each be assigned to separate targets, greatly increasing the destructive potential of a country's arsenal. MIRVs were a major technological advance during the cold war, but also increased instability because they were considered to increase the value of striking first in a nuclear confrontation.

of the nuclear stockpile, LLNL conducts regular evaluations of weapons it has developed: the W62 and W87 intercontinental ballistic missile warheads, the W84 ground-launched cruise missile warhead (now in the inactive stockpile), and the B83 bomb. LLNL's surveillance data, peer reviews, and results of experimental and computational simulations inform the Annual Stockpile Assessment by the Departments of Defense and Energy. LLNL is also the lead design lab for the W78 LEP, even though that warhead was designed at Los Alamos.

LLNL's nuclear-weapons-related tasks include:

- **Nuclear weapons research, design, and development.** No new nuclear weapon has been produced since 1990. Today LLNL's design work is focused on LEPs.
- **Testing advanced technology concepts.** "Advanced technology concepts" refers to new ideas for the design or use of nuclear weapons; past examples include improving the use control of nuclear weapons and examining using nuclear weapons to destroy chemical and biological agents.
- **Plutonium and tritium research and development.** Plutonium is used in the primary of U.S. nuclear weapons; tritium is used to boost the primary's yield.
- **Hydrotesting and environmental testing.** Hydrotests experimentally simulate the conditions in an exploding nuclear weapon and environmental tests assess the effects of a nuclear detonation on various materials.
- **High explosive research and development.** The high explosive in a nuclear weapon surrounds the plutonium pit; when it is detonated it compresses the nuclear material, leading to nuclear detonation.

In addition to nuclear weapons work, LLNL also works to prevent nuclear proliferation and nuclear terrorism, develop capabilities to counter terrorism and other emerging threats, research new military technologies, better understand climate change and its impacts, and develop technologies for low-carbon energy. It houses some of the most powerful supercomputing capabilities in the world, which help carry out simulations for the Stockpile Stewardship Program.

The lab has about 6,800 employees at its main site and Site 300. After decades as a nonprofit managed by the University of California, LLNL is now run by the for-profit Lawrence Livermore National Security, LLC. This corporation was established in 2007 and comprises Bechtel National, the University of California, the Babcock & Wilcox Company, the Washington Division of URS Corporation, and Battelle.

## Budget

LLNL's FY 2013 budget is $1.19 billion, of which $981 million (82 percent) is for weapons activities.[3] Within that category, the largest amount is $272 million for the Inertial Confinement Fusion and High Yield Campaign, which funds the National Ignition Facility. The Advanced Simulation and Computing Campaign received $208 million, and $124 million went to directed stockpile work (which includes evaluation, maintenance, and refurbishment of the nuclear stockpile as well as weapons research and development). After weapons activities, the next largest category in the LLNL budget is defense nuclear nonproliferation, funded at $107 million for FY 2013.

For FY 2014, LLNL requested a total of $1.14 billion, $951 million (83 percent) of which is for weapons activities.

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[3] Numbers for FY 2013 are based on the Continuing Resolution annualized for the full year.

# LOS ALAMOS NATIONAL LABORATORY

Los Alamos, NM, is the birthplace of the U.S. nuclear weapons program, where the primary research, design, and production of the first U.S. nuclear weapons took place. Today, Los Alamos National Laboratory (LANL) is one of three privately managed DOE facilities that conduct research and design on the U.S. nuclear weapons stockpile, along with Lawrence Livermore National Laboratory and Sandia National Laboratories.

## Los Alamos Today

With the end of the cold war and the declaration of a moratorium on full-scale nuclear testing in 1992, LANL's primary mission shifted from developing new warheads to maintaining the safety, security, and reliability of the existing U.S. nuclear stockpile without nuclear explosive testing. LANL conducts life extension programs on existing weapons, which involves replacing components affected by aging with newly manufactured and sometimes modernized components. Under current NNSA plans, future LEPs will entail replacing existing warheads with new ones.

In support of congressional requirements for an annual report certifying the safety, security, and reliability of the nuclear stockpile, LANL conducts regular evaluations of weapons it has developed: the W76 and W88 submarine-launched ballistic missile warheads, the W78 intercontinental ballistic missile warhead, and the B61 nuclear bomb. LANL's surveillance data, peer reviews, and the results of experimental and computational simulations inform the Annual Stockpile Assessment, an initiative administered jointly by the DOE and Department of Defense that certifies the stockpile is safe, reliable, and militarily effective, and meets performance requirements.

LANL performs the following nuclear-weapons-related tasks:

- **Conducts research, design, and development of nuclear weapons.** No new nuclear weapon has been produced since 1990. Today LANL's design work is focused on LEPs.
- **Designs and tests advanced technology concepts.** "Advanced technology concepts" refers to new ideas for the design or use of nuclear weapons; past examples include considering ways to improve the use control of nuclear weapons and examining the utility of nuclear weapons to destroy chemical and biological agents.
- **Maintains production capabilities for limited quantities of plutonium components (i.e., pits) for delivery to the stockpile.** LANL can produce 10 to 20 pits per year and eventually seeks to produce 50 to 80 pits per year.
- **Manufactures nuclear weapon detonators for the stockpile.** LANL is the sole bulk producer of this key warhead component, which initiates detonation of the high explosive that, in turn, compresses the plutonium pit.
- **Conducts tritium research and development (R&D), hydrotesting, high explosives R&D, and environmental testing.** Tritium is used to boost the yield of the primary; hydrotests experimentally simulate the conditions in an exploding nuclear weapon; and environmental tests assess the effects of a nuclear detonation on various materials.
- **Currently maintains Category I/II quantities of special nuclear materials (quantities that require the highest level of security).** For ease of protection, the plan is for this material to be moved to a single consolidated location.

In addition to work on the U.S. nuclear stockpile, LANL performs work to reduce the threat of weapons of mass destruction, nuclear proliferation, and terrorism, and conducts research on other defense, energy, and environmental issues such as electricity delivery and energy reliability; energy efficiency; nuclear, renewable, and fossil energy; and the cleanup of radioactive and otherwise contaminated portions of the site. It also maintains some of the most powerful supercomputing capabilities in the world, which help it to carry out the simulations used for the Stockpile Stewardship Program.

After decades of being managed by the University of California and run as a nonprofit, LANL is now managed by a for-profit limited liability company, Los Alamos National Security (LANS). This corporation was established in 2006 and is made up of Bechtel National, the University of California, BWX Technologies, and URS Energy and Construction, Inc. The lab employs a total of about 10,300 people.

Los Alamos National Laboratory and town, 2006

## Budget

LANL's total FY 2013 budget is roughly $1.8 billion.[4] Of this, most—$1.3 billion—comes from the NNSA for nuclear weapons activities, with additional NNSA funding for nuclear nonproliferation efforts. LANL also receives funding from the DOE for environmental management (cleanup related to defense nuclear programs), site security, and energy programs.

For FY 2014, LANL has requested a total of nearly $2 billion in funding, with $1.4 billion of this for weapons activities. The largest line item in LANL's FY 2014 weapons activities budget request ($460 million) is for directed stockpile work, part of the Stockpile Stewardship Program that supports current and future LEPs and includes surveillance and maintenance activities. The second-largest budget line ($302 million) within the weapons program is for site stewardship (that is, the operation and maintenance of NNSA program facilities; much of this funding previously fell under the Readiness in Technical Base and Facilities category, which NNSA has discontinued in FY 2014).

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[4] Numbers for FY 2013 are based on the Continuing Resolution annualized for the full year.

Photo: Los Alamos National Laboratory

# NEVADA NATIONAL SECURITY SITE

The Nevada National Security Site (NNSS) is where the United States carried out most of its explosive tests of nuclear weapons (the vast majority of them underground). When the United States signed the Threshold Test Ban Treaty in 1974, it became the only U.S. nuclear weapons test site. Originally known as the Nevada Proving Grounds, and then as the Nevada Test Site, the facility was renamed in 2010 when its mission was expanded to encompass a broader range of activities related to nuclear weapons, energy, and homeland security needs.

The NNSS is located in the desert, about 75 miles northwest of Las Vegas. The site itself covers more than 1,300 square miles and is surrounded by the federally owned Nevada Test and Training Range that acts as a buffer, giving a total unpopulated area of more than 5,400 square miles—nearly the size of the state of Connecticut. Its remote location and large size were important factors in its selection as a testing site.

## The NNSS Today

With the end of the cold war and the 1992 moratorium on nuclear explosive testing, the NNSS's primary mission shifted from the explosive testing of nuclear weapons to maintaining the safety, security, and reliability of the existing U.S. nuclear stockpile without such testing. (Under a 1993 presidential decision directive, the site must maintain a state of readiness to resume nuclear explosive testing within two to three years if the president directs it to do so.)

The NNSS is still a major test site for the U.S. nuclear complex, but the tests that take place there no longer involve nuclear explosions. Instead, it is home to several unique facilities that contribute to its stockpile stewardship mission. These include:

- **The U1a Complex** (previously known as the Lyner Complex), an underground laboratory where subcritical testing takes place. Subcritical tests, which use small amounts of plutonium but not enough to generate a chain reaction, help improve understanding of the dynamic properties of weapons parts or materials in an explosion and evaluate the effects of new manufacturing techniques on weapon performance.
- **The Big Explosives Experimental Facility (BEEF)**, where hydrodynamic testing using high explosives is performed. The term hydrodynamic is used because the explosive material is compressed and

Subsidence craters at Yucca Flat at the Nevada National Security Site, where hundreds of full-scale underground nuclear tests were performed until the United States halted such testing in 1992.

heated with such intensity that it begins to flow and mix like a fluid, and the equations used to describe the behavior of fluids—called hydrodynamic equations—can be used to describe the behavior of this material as well. This testing helps to assess the performance of nuclear weapons and ensure that they will not detonate accidentally; it does not involve any special nuclear materials (e.g., plutonium or highly enriched uranium).

- **The Joint Actinide Shock Physics Experimental Research (JASPER) Facility**, which simulates the intense shock pressures and temperatures of a nuclear weapon using a two-stage gas gun. Data from JASPER hydrodynamic experiments are used to develop equations that express the relationship between temperature, pressure, and volume of the materials used in nuclear weapons and to validate weapons computer models.
- **The Device Assembly Facility (DAF)**, made up of more than 30 buildings, including special structures (called bays and cells) for assembling and disassembling nuclear weapons, and staging bunkers for temporarily storing nuclear components and high explosives. In 2012, the DAF was upgraded to allow it to assemble the plutonium targets for the JASPER Facility, a task previously done at Lawrence Livermore National Laboratory. The NNSA is also developing a capability at the DAF to dismantle and dispose of damaged weapons or improvised nuclear devices (such as "dirty bombs") that might be made by terrorists.
- **The National Criticality Experiments Research Center (NCERC)**, housed at the DAF, is the only site in the United States where such experiments take place. By bringing a small amount of plutonium or highly enriched uranium into a chain reaction, these experiments help define the limits of safe handling and allow testing of radiation detection equipment. Criticality experiments were previously carried out at Technical Area 18 (TA-18) at Los Alamos National Laboratory. After the NNSA decided in 2002 to close TA-18 due to concerns that it would be difficult to defend against armed attackers seeking to acquire nuclear materials, the capability was transferred to the NNSS. The NCERC officially opened on August 29, 2011.

In addition to its tasks supporting the Stockpile Stewardship Program, the NNSS also provides a testing site to evaluate detection, monitoring, and verification technologies used in nuclear nonproliferation and arms control applications, and helps manage the nation's nuclear emergency response efforts. Other federal agency activities are supported by the NNSS as well, such as remote imaging and training first responders to deal with nuclear or radiological emergencies.

The NNSS is operated by National Security Technologies, LLC, which is a partnership of Northrup Grumman, AECOM, CH2M Hill, and Nuclear Fuel Services. The site employs roughly 1,900 scientific, technical, engineering, and administrative personnel.

## Budget

The NNSS's total FY 2013 funding from the DOE is $383 million.[5] Of this, the majority—$257 million—came from the NNSA for weapons activities, with an additional $67 million in NNSA funding for nuclear nonproliferation.

In FY 2014 the NNSS requested a total of $396 million in funding, with $244 million of this for weapons activities. Within the weapons activities request, the largest line item is $125 million for site stewardship (that is, the operation and maintenance of NNSA facilities; much of this funding previously fell under the Readiness in Technical Base and Facilities category, which the NNSA discontinued in FY 2014). The NNSS also requested $110 million for defense nuclear nonproliferation and $42 million for defense environmental cleanup in FY 2014. The jump in the funding request for nonproliferation reflects another change in the NNSA's organization of the FY 2014 budget, which moved funding for the nuclear counterterrorism incident response program, previously in the weapons category, to nonproliferation.

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[5] Numbers for FY 2013 are based on the Continuing Resolution annualized for the full year.

Photo: (left) NNSA Nevada Field Office

# PANTEX PLANT

The Pantex Plant, located near Amarillo, TX, was originally a World War II Army site for loading and packing artillery shells and building bombs. Pantex, short for "panhandle of Texas," closed after the war, reopening in 1951 as a facility to handle nuclear weapons, high explosives, and non-nuclear component assembly operations. Since the 1975 closure of the Burlington Atomic Energy Commission Plant in Iowa, Pantex has been the only facility in the United States where nuclear weapons are assembled and disassembled. With the closure of Colorado's Rocky Flats plutonium plant in 1989, Pantex also became the interim storage site for plutonium pits.

## Pantex Today

After the United States halted production of nuclear weapons in 1991, Pantex's major responsibilities shifted from assembling nuclear weapons to refurbishing existing warheads to extend their lifetimes and disassembling retired weapons. Under the Stockpile Stewardship Program, Pantex is responsible for assembly, disassembly, maintenance, and surveillance of nuclear weapons and weapons components in the stockpile to ensure their safety, reliability, and military effectiveness.

Pantex conducts life extension programs on existing weapons. This involves replacing components affected by aging with newly manufactured and sometimes modernized components. One of its tasks is limited-life component exchange, in which warhead components that age in predictable ways (e.g., power sources, neutron generators) are replaced at regular intervals before their deterioration affects weapons' performance.

Pantex has conducted LEPs on W87 warheads and some types of B61 bombs so far, and is currently conducting an LEP on the W76. Additional LEPs, some more far-reaching than those done to date, are planned for the rest of the warheads in the stockpile.

In addition to its stockpile stewardship work, Pantex's missions include:

- Dismantling retired warheads by separating the high explosive from the plutonium pit
- Interim storage of components from dismantled warheads, including the pits
- "Sanitizing" (removing classified information) and disposing of dismantled weapons components
- High explosive research and development
- Producing and testing the high explosive components for nuclear weapons


Pantex Plant, 2007

Photo: NNSA News

To carry out its missions, Pantex maintains Category I/II quantities of special nuclear materials, which can be used to make nuclear weapons and require the highest level of security.[6]

The lab has about 3,600 employees, and is managed by a limited liability company formed solely for this purpose, Babcock and Wilcox Technical Services Pantex (B&W Pantex). The company is made up of BWX Technologies, Honeywell International, and Bechtel National.

## Budget

Pantex's overall budget for FY 2013 is $587 million, virtually all of which comes from the NNSA for weapons activities work.[7] Within this category, 34 percent of Pantex's funding is for directed stockpile work (which includes both LEPs and dismantlement of retired weapons); 39 percent is for readiness in technical base and facilities (that is, operation and maintenance of NNSA facilities); and 22 percent is for defense nuclear security (for protection of the site).

Information about funding for Pantex was not included in the FY 2014 Laboratory Tables put out by the NNSA. However, the overall NNSA budget request includes roughly $604 million in funding for Pantex under the NNSA Production Office, with about $602 million of this for weapons activities. Because the request is not broken down further, it is not possible at this point to determine how much funding will go to specific weapons activities programs in FY 2014.

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[6] These include plutonium-239, uranium-233, and uranium enriched in the isotopes uranium-233 or uranium-235. Materials are classified as Category I to IV depending on how much is present and their ease of use for making nuclear weapons.

[7] Numbers for FY 2013 are based on the Continuing Resolution annualized for the full year.

# SANDIA NATIONAL LABORATORIES

Sandia National Laboratories (SNL) is responsible for the non-nuclear components and systems integration of U.S. nuclear weapons. Often called the engineering laboratory of the U.S. nuclear weapons complex, it grew out of Z Division, the ordnance design, testing, and assembly branch of Los Alamos during World War II. Z Division moved to Sandia Base, outside Albuquerque, NM, to have easier access to an airfield and work more closely with the military.

In 1948, Z Division became Sandia Laboratory, and in 1956 a second Sandia site was established in Livermore, CA; these two locations ensure proximity to the other two U.S. nuclear weapons research and design facilities—Los Alamos and Lawrence Livermore—that design the nuclear explosive packages for all U.S. weapons.

SNL also operates the Tonopah Test Range (TTR) in Nevada and the Weapons Evaluation Test Laboratory (WETL) at the Pantex Plant in Texas; it has five additional satellite sites around the country.

## Sandia Today

With the end of the cold war and the 1992 moratorium on nuclear explosive testing, SNL's primary mission shifted from developing components for new nuclear weapons to maintaining the safety, security, and reliability of the existing U.S. nuclear stockpile without nuclear testing.

In support of congressional requirements for an annual report certifying the safety, security, and reliability of the U.S. nuclear weapons stockpile, SNL conducts regular evaluations of non-nuclear components of these weapons. SNL's surveillance data, peer reviews, and the results of experimental and computational simulations inform the Annual Stockpile Assessment by the Departments of Defense and Energy.

To carry out its assessment, SNL relies on facilities like the WETL, the Z machine at its Albuquerque site, and the TTR. The WETL evaluates weapons subsystems to identify defects in the stockpile. The Z machine helps scientists understand how plutonium reacts during a nuclear detonation by generating powerful X-rays that mimic the high pressure and heat levels in a detonating nuclear warhead. At the TTR, drop tests are conducted with joint test assemblies—bombs pulled from the stockpile that have had their nuclear material removed. On average, 10 such tests per year are conducted.

Sandia's main weapons-related tasks include:

- **Systems engineering of nuclear weapons.** SNL is responsible for the integration of the nuclear explosive package with the non-nuclear components of the warhead.
- **Research, design, and development of non-nuclear components of nuclear weapons.** SNL is responsible for most non-nuclear weapons components, and continues to conduct research on these, especially on weapons surety (safety, access control, and use control) and on how component materials are affected by aging.
- **Manufacture of some non-nuclear components.** The Kansas City Plant in Missouri produces most non-nuclear components, but SNL manufactures some specialized components, like neutron generators (the "trigger" that initiates the fission reaction in a nuclear weapon) and microelectronics; it also maintains a backup capability to produce batteries and high explosive components.
- **Safety, security, and reliability assessments of stockpile weapons.** The most high-profile element of this work is the annual report certifying that warheads in the stockpile remain reliable, safe, and secure.
- **High explosive (HE) research and development.** SNL, along with Pantex, is responsible for research and development on the HE material that surrounds the fissile core of a nuclear weapon and compresses the plutonium in the pit, leading to nuclear detonation.
- **Environmental testing.** Environmental testing assesses the effects of environmental conditions (e.g., shock, high temperatures, vibration) on nuclear weapons, to simulate the conditions they may be subjected to during delivery to their targets. Since the end of nuclear explosive testing, much of this testing at SNL has addressed the need to ensure that nuclear weapons components are sufficiently hardened to withstand the radiation of a nuclear explosion (e.g., from another weapon delivered to the same target).

In addition to its nuclear weapons mission, SNL conducts research and development on nuclear nonproliferation, nuclear counterterrorism, energy security, defense, and homeland security. It also provides engineering design and support for the NNSA Office of

Sandia National Laboratories, Albuquerque, NM, 2009

Secure Transportation, which transports nuclear weapons, components, and special nuclear materials (SNM).

As part of the NNSA's plan to consolidate weapons-usable materials in the nuclear weapons complex, SNL in 2008 became the first NNSA site to remove all Category I and II SNM (the categories requiring the highest level of security).

SNL is operated by Sandia Corporation, a subsidiary of Lockheed Martin Corporation. It employees nearly 10,700 workers across all its sites, including about 9,300 at its main site in New Mexico, and another 1,000 in California.

## Budget

SNL's total FY 2013 funding from the DOE is roughly \$1.8 billion.[8] Of this, the majority—\$1.4 billion—comes from the NNSA for nuclear weapons activities, with additional NNSA funding for nuclear nonproliferation. SNL also receives DOE funding for environmental management (cleanup related to defense nuclear programs), site security, and energy research and development. Unlike the other weapons labs, which are funded almost exclusively by the DOE, a large portion of SNL's annual budget (about one-third in FY 2011, the last year for which data are currently available) comes from non-DOE sources for "work for others"—research or other work for private companies or other government agencies.

SNL requested a total of \$1.8 billion for FY 2014, of which roughly \$1.5 billion was for weapons activities. The largest line item in SNL's FY 2014 weapons activities budget request (\$871 million) is for directed stockpile work, part of the Stockpile Stewardship Program that supports current and future life extension programs, and includes surveillance and maintenance activities. The second-largest budget line (\$171 million) within the weapons category is for site stewardship (that is, the operation and maintenance of NNSA program facilities; much of this funding previously fell under the Readiness in Technical Base and Facilities category, which the NNSA discontinued in FY 2014). SNL also requested \$128 million for the Advanced Simulation and Computing Campaign, which funds high-end simulation capabilities for weapons assessment and certification and to predict the behavior of nuclear weapons.

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[8] Numbers for FY 2013 are based on the Continuing Resolution annualized for the full year.

Photo: NNSA News

# SAVANNAH RIVER SITE

The Savannah River Site (SRS) is located in South Carolina, near the Georgia border. For most of its history, it produced radioactive materials for the U.S. nuclear weapons program. From 1953 to 1988, five reactors at the site produced plutonium-239 and tritium (a radioactive form of hydrogen). During this period, the SRS produced 36 metric tons of plutonium-239, about 35 percent of the plutonium produced by the DOE for use in nuclear weapons.

The SRS sits on 310 square miles of land and has about 12,000 employees. It is owned by the DOE and given the amount of cleanup required—37 million gallons of radioactive liquid waste are stored in 49 underground tanks, leading to its declaration as a Superfund site—the DOE Office of Environmental Management is the "site landlord." The NNSA operates the SRS tritium facilities. Savannah River Nuclear Solutions, LLC, a partnership including Fluor Daniel, Northrup Grumman, and Honeywell, manages and operates the SRS for the NNSA.

## The Savannah River Site Today

With reductions in the U.S. nuclear arsenal after the end of the cold war, the SRS's mission shifted to maintaining the current arsenal, disposing of excess nuclear materials, and cleanup of the site. Today the SRS is a key site in the Stockpile Stewardship Program (a program for maintaining the safety, security, and reliability of U.S. nuclear weapons without nuclear testing). It is also the primary disposition site for most surplus weapons-grade plutonium and some surplus highly enriched uranium (HEU).[9]

### Tritium Production

The SRS's role in the Stockpile Stewardship Program focuses on tritium and related weapons components. Tritium gas, used with deuterium gas (a nonradioactive isotope of hydrogen) to boost the yield of U.S. nuclear weapons, decays over time and must be periodically replenished to maintain the weapons' effectiveness. The SRS stopped producing tritium in 1988. To meet current needs, it now recycles tritium from dismantled warheads and extracts tritium produced in the Tennessee Valley Authority's (TVA's) Watts Barr reactor in Tennessee.

The SRS periodically replenishes the tritium reservoirs in existing nuclear weapons as part of the Limited Life Component Exchange (LLCE) program. The Department of Defense (DOD) sends tritium reservoirs at the end of their useful life to the SRS to be emptied and refilled with a precise mixture of tritium and deuterium gases, then sent back to the DOD or to the Pantex Plant in Texas for replacement in weapons.

As part of stockpile surveillance, the SRS also performs reliability testing on the gas transfer systems that inject the tritium-deuterium gas from the reservoir into the plutonium pit as the fission reaction begins.

### Plutonium and HEU Disposal

Two new facilities at the SRS are under construction to support plutonium disposition: the Mixed Oxide Fuel Fabrication Facility (MFFF) and the Waste Solidification Building, with the latter nearly complete. A third, the Pit Disassembly and Conversion Facility, has been canceled due to budget constraints and the availability of alternatives.

Plans call for most surplus plutonium at the SRS to be converted to plutonium oxide and used to fabricate mixed oxide (MOX) fuel for use in commercial nuclear reactors. Plutonium too impure for use in MOX fuel will be sent to either the Waste Isolation Pilot Plant in New Mexico or the existing Defense Waste Processing Facility at the SRS, where it will be "vitrified"—converted to a glass form suitable for long-term storage.

In its FY 2014 budget request, the NNSA has decided to slow the MFFF project while the contractor reviews the program and provides updated cost and schedule estimates, and the administration conducts an assessment of alternative strategies for disposing of the excess plutonium. This decision was based on continually increasing cost estimates and delays. The project is now 14 years behind schedule, and its estimated operational date has continued to slip, from 2016 to 2019, according to the most recent NNSA analysis. Costs have also risen from the original 2002 estimates of less than $1 billion for design and construction and

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[9] HEU contains greater than 20 percent uranium-235 (U-235) or U-233; low-enriched uranium contains less than 20 percent. In contrast, natural uranium contains less than 1 percent U-235. HEU comprising more than 90 percent U-235 is considered weapons-grade uranium, although all HEU can be used to make nuclear weapons. Weapons-grade plutonium is largely plutonium-239 (Pu-239) and contains less than 7 percent Pu-240.

**Savannah River Site, 2012**

$156 million per year for operations to $7.7 billion and more than $500 million per year, respectively. The future of the project will depend on the outcome of the contractor and administration reviews.

The HEU disposed of at the SRS comes from spent fuel from domestic and foreign research reactors, as well as excess HEU-bearing materials from other DOE sites. The spent fuel is dissolved in acid to separate the HEU, which is blended with natural uranium to create a low-enriched uranium solution that is sent to the TVA to be turned into fuel for its commercial reactors.

### Other Missions

The SRS is involved in environmental stewardship, environmental cleanup, and research on renewable and other low-carbon energy sources. It also houses the Savannah River National Laboratory, which works on national and homeland security, energy security, and environmental and chemical process technology.

### Budget

The SRS's FY 2013 budget is approximately $1.6 billion, with $1.3 billion of that going to defense environmental cleanup to decontaminate areas of the site that were associated with nuclear weapons production.[10]

For FY 2014, the SRS has requested a total of $1.4 billion in funding, $1.2 billion of which is for defense environmental cleanup. As noted above, the MOX project has been slowed for FY 2014 and its funding reduced, falling from $438 million in FY 2013 to $320 million in FY 2014, a reduction of 27 percent.

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[10] Numbers for FY 2013 are based on the Continuing Resolution annualized for the full year.

Photo: NNSA News

# Y-12 NATIONAL SECURITY COMPLEX

The Y-12 National Security Complex was part of the original Manhattan Project, producing enriched uranium for the "Little Boy" bomb dropped on Hiroshima in 1945. The site takes its name from the World War II code name for the electromagnetic isotope separation plant at the Clinton Engineer Works in Oak Ridge, TN. During the cold war, Y-12 enriched uranium through electromagnetic separation and later gaseous diffusion, and manufactured nuclear weapons components from uranium and lithium.

The site includes the Y-12 plant, Oak Ridge National Laboratory, and the East Tennessee Technology Park. B&W Y-12, a partnership between Babcock & Wilcox Company and Bechtel Corporation, manages the Y-12 site; it employs about 4,600 workers.

## Y-12 Today

Today Y-12 is one of four production facilities in the U.S. nuclear weapons complex; it focuses on uranium processing and storage and development of related technologies. Its missions are to maintain the safety, security, and effectiveness of the U.S. nuclear weapons stockpile; reduce the global threat of nuclear proliferation and terrorism; and provide highly enriched uranium for use in U.S. naval reactors.

Y-12 produces all U.S. nuclear weapons secondaries, canned subassemblies (CSAs), and radiation cases. U.S. thermonuclear weapons have two stages: a primary and a secondary. The secondary contains HEU and is contained within a CSA. A uranium-lined radiation case encloses both the primary and CSA. Y-12 is also the main U.S. site for processing and storing HEU for nuclear weapons use.

Y-12's additional nuclear-weapons-related tasks include:

- Performing quality evaluation and surveillance activities on subassemblies and components
- Maintaining Category I/II quantities of HEU, which can be used to build nuclear weapons and require the highest level of security
- Dismantling secondaries, radiation cases, and other weapons components
- Storing and disposing of enriched uranium

Y-12 has completed work on life extension programs for two weapons: the W87 intercontinental ballistic missile warhead and the B61-7 and B61-11 strategic nuclear bombs. The B61 LEP included refurbishment of its CSA. It is now working on an LEP of the W76 submarine-launched ballistic missile warhead, which is scheduled to be completed in 2022.

Y-12 also supplies the Navy with HEU from dismantled weapons to make fuel for use in the nuclear reactors that power all U.S. submarines and aircraft


Y-12 National Security Complex, 2011

Photo: NNSA NewsR

carriers. An agreement with the Department of Defense requires Y-12 to provide HEU through 2050.

In addition to weapons work, Y-12's mission includes preventing nuclear proliferation and nuclear terrorism. Its main tasks in this area include securing and removing uranium and nuclear materials from vulnerable sites globally, developing technologies to detect uranium as part of treaty verification and border control, and disposing of excess HEU from dismantled weapons by converting it to low-enriched uranium (LEU) for civil use.

In 1994 the United States declared 174 metric tons of HEU to be excess to military needs. Much of this has already been down-blended; the rest is to be converted by 2015. About 10 percent of excess HEU is down-blended at Y-12 for use as fuel in research reactors or to produce medical isotopes. Y-12 is the primary provider of LEU for research reactors worldwide. Remaining excess HEU is shipped to the Savannah River Site or a commercial facility in Lynchburg, VA, to be down-blended for use as fuel in nuclear power reactors.

## Budget

Y-12's FY 2013 budget is $982 million; $961 billion (98 percent) of this is for weapons activities.[11] Within that category, the largest appropriation was $729 million for Readiness in Technical Base and Facilities (that is, operation and maintenance of NNSA facilities). Another $215 million went to directed stockpile work, part of the Stockpile Stewardship Program that supports LEPs and weapons surveillance and maintenance activities. After weapons activities, the next-largest budget category at Y-12 is defense nuclear nonproliferation, funded at $21 million for FY 2012.

Information about funding for Y-12 was not included in the FY 2014 Laboratory Tables put out by the NNSA. However, the overall NNSA budget request includes roughly $1.2 billion in funding for Y-12 under the NNSA Production Office, with nearly all of this (96 percent) for weapons activities. Within the weapons activities category, about $325 million is for the Uranium Processing Facility.

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[11] Numbers for FY 2013 are based on the Continuing Resolution annualized for the full year.

# About the Authors

**Lisbeth Gronlund, senior scientist and co-director, Global Security Program, Union of Concerned Scientists**

Dr. Gronlund holds a doctorate in physics from Cornell University. Her research focuses on technical issues related to U.S. nuclear weapons policy, ballistic missile defense, and nuclear arms control.

Gronlund is a fellow of the American Physical Society (APS) and the American Association for the Advancement of Science. She received the 2001 Joseph A. Burton Forum Award of the APS "for creative and sustained leadership in building an international arms-control-physics community and for her excellence in arms control physics."

Before joining the Union of Concerned Scientists, Gronlund was a Social Science Research Council–MacArthur Foundation fellow in international peace and security at the University of Maryland, and a postdoctoral fellow at the Defense and Arms Control Studies Program of the Massachusetts Institute of Technology (MIT).

**Eryn MacDonald, analyst, Global Security Program, Union of Concerned Scientists**

Ms. MacDonald holds a master's degree in government from Cornell University. Her research areas include the U.S. nuclear complex, arms control and nonproliferation, and East Asian security. Before coming to UCS, she coordinated internships for the International Science and Technology Initiative at MIT.

**Stephen Young, senior analyst, Global Security Program, Union of Concerned Scientists**

Mr. Young holds a master's degree in international affairs from Columbia University. His areas of expertise include arms control, nuclear weapons policy, ballistic missile defense, and nuclear threat reduction programs. In addition to his research, he meets frequently on these issues with administration officials, members of Congress, and journalists.

Before joining UCS, Young was deputy director of the Coalition to Reduce Nuclear Dangers, a national alliance of 17 nuclear arms control organizations. He previously served as a senior analyst at the British American Security Information Council, legislative and field director for 20/20 Vision, and senior information specialist at ACCESS, a security information clearinghouse. He also was a fellow in the U.S. State Department's Bureau of Human Rights.

**Hon. Philip E. Coyle III, senior science fellow, Center for Arms Control and Non-Proliferation**

Mr. Coyle is an expert on U.S. and worldwide military research, weapons development and testing, operational military matters, and national security policy and defense spending.

In 2010 and 2011 he served as associate director for national security and international affairs in the White House Office of Science and Technology Policy. In this position he supported the universities and laboratories that comprise the R&D capabilities of the Department of Defense, the Department of Energy, and other agencies. From 2001 to 2010, Coyle served as a senior advisor to the president of the World Security Institute and its Center for Defense Information.

In 2005 and 2006, Coyle served on the Defense Base Realignment and Closure Commission (BRAC), appointed by President George W. Bush. From 1994 to 2001, he was assistant secretary of defense, and director of operational test and evaluation for the Department of Defense.

From 1979 to 1981, Coyle served as principal deputy assistant secretary for defense programs in the Department of Energy. In this capacity he had oversight responsibility for the department's nuclear weapons research, development, production, and testing programs, as well as its programs in arms control, nonproliferation, and nuclear safeguards and security. From 1959 to 1979, and again from 1981 to 1993, Coyle held positions at Lawrence Livermore National Laboratory (LLNL) working on a variety of nuclear weapons programs and other high-technology programs. He also served as deputy associate director of the Laser Program at LLNL.

### Steve Fetter, professor, School of Public Policy, University of Maryland

Dr. Fetter has been a professor at the School of Public Policy since 1988, serving as dean from 2005 to 2009. He is currently associate provost for academic affairs. He received a doctorate in energy and resources from the University of California–Berkeley. His research and policy interests include nuclear arms control and nonproliferation, nuclear energy and releases of radiation, and climate change and low-carbon energy supply.

From 2009 to 2012, Fetter served as assistant director at large in the White House Office of Science and Technology Policy. Previously, he was special assistant to the assistant secretary of defense for international security policy, and served in the State Department as an American Institute of Physics fellow and a Council on Foreign Relations international affairs fellow. He has been a visiting fellow at Stanford's Center for International Security and Cooperation, Harvard's Center for Science and International Affairs, MIT's Plasma Fusion Center, and Lawrence Livermore National Laboratory.

Fetter has also served on the National Academy of Sciences' Committee on International Security and Arms Control, the Department of Energy's Nuclear Energy Research Advisory Committee, the Director of National Intelligence's Intelligence Science Board, and the board of directors of the Arms Control Association. He is a member of the Council on Foreign Relations and a fellow of the American Physical Society.

Photo: Ken Lund/Flickr

**An entrance to what was formerly known as the Nevada Test Site, where the United States conducted hundreds of full-scale nuclear weapons tests, first aboveground and then underground. It is still used to conduct tests with nuclear material, but on a limited scale with smaller amounts of such material.**

# Making Smart Security Choices

## The Future of the U.S. Nuclear Weapons Complex

The mission of the U.S. nuclear weapons complex—the laboratories and facilities that research, design, produce, maintain, and dismantle such weapons—is to ensure that the arsenal is reliable, safe from accidents, secure from unauthorized use, and no larger than needed to maintain national security.

To fulfill those goals, the complex needs to have the resources and facilities to extend the life of nuclear warheads, assess their reliability and safety, understand the impact of aging and modifications to them, and retain employees with essential scientific and technical expertise. The complex also requires the capacity to dismantle retired weapons in a timely fashion, and to develop methods for verifying further reductions in nuclear weapons. The complex must also minimize the security risks entailed in storing, transporting, and disposing of weapons-usable materials.

Finally, the complex must meet all these challenges with limited resources. Doing so will require making smart choices based on strict attention to priorities.

The administration and Congress will make important decisions on the nuclear weapons complex over the next few years. To inform those decisions, this report examines the essential missions of the complex, considers its key challenges, and suggests critical near-term and long-term steps.

Union of Concerned Scientists

This report is available online (in PDF format) at *www.ucsusa.org/smartnuclearchoices.*

The Union of Concerned Scientists puts rigorous, independent science to work to solve our planet's most pressing problems. Joining with citizens across the country, we combine technical analysis and effective advocacy to create innovative, practical solutions for a healthy, safe, and sustainable future.

**National Headquarters**: Two Brattle Square, Cambridge, MA 02138-3780 • Phone: (617) 547-5552 • Fax: (617) 864-9405
**Washington, DC, Office**: 1825 K St. NW, Suite 800 • Washington, DC 20006-1232 • Phone: (202) 223-6133 • Fax: (202) 223-6162
**West Coast Office**: 2397 Shattuck Ave., Suite 203 • Berkeley, CA 94704-1567 •Phone: (510) 843-1872 •Fax: (510) 843-3785
**Midwest Office**: One N. LaSalle St., Suite 1904 •Chicago, IL 60602-4064 • Phone: (312) 578-1750 •Fax: (312) 578-1751

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