CBO PAPERS

PRESERVING THE NUCLEAR WEAPONS STOCKPILE UNDER A COMPREHENSIVE TEST BAN

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CONGRESSIONAL BUDGET OFFICE

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SECOND AND D STREETS, S.W.
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NOTES

Unless otherwise indicated, all years referred to in this paper are fiscal years.

Numbers in the text and tables may not add up to totals because of rounding.

PREFACE

In September 1996, President Clinton signed the Comprehensive Test Ban Treaty, which will prohibit all explosive testing of nuclear weapons. In addition, under the terms of the Strategic Arms Reduction Treaties, the United States plans to significantly reduce the size of its stockpile of nuclear weapons.

How can the United States preserve the reliability and safety of its nuclear stockpile without recourse to explosive testing? The Department of Energy's answer is the Stockpile Stewardship and Management Program, which will build myriad experimental facilities and computers that will allow scientists to study the effects of aging on weapons by simulating some of the conditions in an exploding warhead. The department also intends to consolidate its production facilities and develop new techniques to assess the condition of weapons that remain in the stockpile.

This Congressional Budget Office (CBO) paper describes the Administration's plan for stockpile stewardship and management and examines four alternatives that the Congress may wish to consider. It was requested by the Ranking Minority Member of the Senate Committee on Governmental Affairs. In keeping with CBO's mandate to provide impartial analysis, the paper makes no recommendations.

David Mosher of CBO's National Security Division prepared the paper under the direction of Cindy Williams and R. William Thomas. Raymond Hall and Elizabeth Chambers of the Budget Analysis Division analyzed costs under the direction of Michael Miller. Nathan Stacy researched and wrote the section describing how nuclear weapons work. Jofi Joseph thoroughly reviewed the manuscript and provided helpful comments; he and Doug Taylor provided invaluable analytic assistance. The author also appreciates the thoughtful critiques and suggestions of Tom Zamora Collina and others outside CBO. Many people at the Department of Energy, the three weapons laboratories, and the Nevada Test Site were extraordinarily helpful; their efforts are gratefully acknowledged. However, all responsibility for the analysis lies with the author and CBO.

Christian Spoor edited the manuscript, and Marlies Dunson provided editorial assistance. Cindy Cleveland prepared the paper for publication.

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Director

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CONTENTS

TABLES

FIGURES

BOXES

SUMMARY

The end of the Cold War has changed the way the Department of Energy (DOE) does business. In the past, DOE was responsible for designing and building new nuclear weapons, maintaining the ones in the stockpile, and dismantling weapons that had been retired. But because of changes in U.S. policy—including a unilateral moratorium on all explosive nuclear testing—the department no longer designs or builds new types of weapons. Also, recent unilateral and bilateral arms control measures have prompted the United States to shrink its nuclear stockpile, so DOE has fewer weapons to maintain.

Today, the department's weapons program focuses primarily on maintaining the performance, reliability, and safety of the existing nuclear stockpile—a stockpile that must now last for decades without new weapons. Furthermore, DOE must carry out those tasks without the benefit of exploding weapons in underground tests to see whether they work. The United States has not conducted such a test since 1992. And by signing the Comprehensive Test Ban Treaty (CTBT) in September 1996, the President has signified that he intends to have the United States forgo underground testing indefinitely.

DOE plans to adapt its weapons complex to those new realities through the Stockpile Stewardship and Management Program. This paper examines that program and some alternatives that the Congress might consider. The alternatives cover a wide range of possible changes: keeping the size of the nuclear stockpile at present levels instead of carrying out planned reductions, making much deeper cuts in the stockpile, trying to carry out DOE's current plans at a lower cost, or scaling back the department's stewardship effort to a minimal level. Three of the four alternatives would save money compared with DOE's planned spending of about $4 billion a year. That could be an important consideration for the Congress as it faces continuing pressure to balance the federal budget.

THE POLITICAL AND MILITARY CONTEXT

The end of the Cold War has wrought several changes that will have a profound effect on the Department of Energy. One of the largest is the Comprehensive Test Ban Treaty, which prohibits all tests in which a nuclear weapon is exploded. President Clinton signed the treaty last September but has not yet submitted it to the Senate for ratification.

The CTBT will have two important consequences for DOE. First, it will reduce the ability of DOE's laboratories to build new types of nuclear weapons, because the reliability and effectiveness of those weapons will not be able to be proved through explosive nuclear testing. As a result, the United States will have to continue relying on its existing types of weapons and keep them in service longer than it ever has before (unless it chooses to eliminate them altogether).

Second, the test ban will limit the tools that the weapons labs have available to verify the reliability, performance, and safety of the enduring stockpile. In the past, if a potentially serious design- or age-related problem emerged, scientists could explode one or more weapons underground to see whether the problem affected the reliability or performance of the warhead. In some cases, they also tested repairs that they made to the weapons in order to certify that the problem had been fixed. Without recourse to explosive testing, weapons scientists will have to use indirect methods to certify the stockpile in the future. (However, it was rare that an underground test was used to determine the effect of a defect on performance or reliability; the vast majority were used to develop new designs and demonstrate that newly manufactured weapons worked.)

Several recent arms control measures will also have an impact on DOE by significantly reducing the number and types of weapons it must support. As a result of unilateral reductions beginning in 1991, the United States has removed the vast majority of its short-range and battlefield nuclear weapons (nearly 7,000 in all) from the stockpile. The first Strategic Arms Reduction Treaty (START I), signed with the Soviet Union in 1991, reduced the number of long-range nuclear weapons that the United States may deploy to 6,000 "accountable" weapons based on its counting rules (although it may actually deploy some 8,500 weapons). The second START treaty—provided that it is ratified by Russia—will reduce the number of deployed long-range weapons to about 3,500. Together, those reductions will cut by more than half the number of weapons that DOE must support in the future, which will allow the department to reduce the size of its production complex.

DOE'S RESPONSE: THE STOCKPILE STEWARDSHIP AND MANAGEMENT PROGRAM

DOE plans to meet the challenge of maintaining and certifying the reliability and safety of the stockpile without underground nuclear testing through its Stockpile Stewardship and Management Program. Under the stewardship effort, the three weapons laboratories—Los Alamos, Lawrence Livermore, and Sandia—will turn their attention to understanding the effects of aging and other problems that could hamper the performance, reliability, and safety of the enduring stockpile. Through the stockpile management effort, DOE will watch for signs of aging even more closely than it has in the past. It will also reconfigure its manufacturing complex to produce more efficiently the smaller quantities of weapons components that will be needed. DOE has consolidated its production facilities at four sites: the Kansas City Plant, Pantex in Texas, Y-12 in Tennessee, and the Savannah River Reservation in South Carolina. In addition, it will produce some components at the weapons labs. Altogether, DOE plans to spend at least $4 billion a year on stockpile stewardship and management through 2010, divided almost evenly between the two efforts.

Science-Based Stockpile Stewardship

Just how DOE should preserve the stockpile under the CTBT has been the subject of intense debate over the past four years within the department, the Administration, the Congress, and nongovernmental groups. The challenges facing weapons scientists under a test ban will be different for nuclear and nonnuclear components. For the most part, nonnuclear components can be tested thoroughly in laboratories and on test ranges without having to explode nuclear weapons. But the prohibition on explosive testing will have a profound effect on the methods that weapons scientists have available to examine nuclear components. Those components include the plutonium pit inside the primary (the fission bomb that serves as a trigger for the fusion reaction in a nuclear weapon) and the secondary (the fusion portion of the weapon).

DOE has decided to pursue a "science-based" stockpile stewardship program that emphasizes building new test facilities to learn as much as possible about how weapons (particularly their nuclear components) work and how age might affect their performance. No one laboratory test can substitute completely for an underground test to verify reliability or performance. At best, it can simulate a small portion of the processes inside an exploding weapon. The laboratories' strategy is to build a number of state-of-the-art facilities that complement each other by simulating different aspects of an exploding weapon. Weapons scientists say the resulting data will help them piece together enough information to understand how aging will affect a weapon's performance and how to correct problems that arise over the years. DOE also expects those facilities to attract new talent to the laboratories—another critical goal of the stewardship program.

In addition to developing new test facilities, the stewardship program will work to improve the computers and computer models that simulate the interactions in an exploding nuclear weapon. That will help scientists better understand how weapons work so they can analyze the effects of aging more accurately. Finally, DOE will retain the ability to resume underground testing within three years (at the request of the President) as a safeguard against a new arms race or an unexpected, serious problem with the stockpile that can be resolved only by exploding nuclear weapons.

Stockpile Management

Whereas the stewardship program will focus on understanding better how nuclear weapons work and age, the stockpile management program will focus on maintaining the weapons, monitoring them for the effects of aging, and fixing any problems by repairing or building new components. To that end, DOE plans to continue its current stockpile surveillance and maintenance programs. However, it will spend an additional $60 million a year to develop new surveillance techniques in order to improve its ability to detect problems as early as possible. DOE believes that the scientific skills and experimental facilities fostered by the stewardship program will help the management program determine how significantly those problems might affect a weapon's reliability and performance.

DOE plans to reduce the size of its production activities to lower costs and to support a START II stockpile more efficiently. However, it intends to maintain as much infrastructure and skilled labor as it believes are necessary to produce new weapons components. Because the existing stockpile must last for the foreseeable future, DOE believes that all components of all types of weapons will eventually have to be replaced. The department also plans to develop and build more durable components, if necessary.

One of the major responsibilities of the stockpile management program will be producing tritium—a radioactive gas that is a critical ingredient in all U.S. nuclear weapons and that must be replaced regularly. To have enough tritium to support the stockpile, DOE must develop a new source. The department closed its last tritium-producing reactor in 1988 because it was old and unsafe. DOE will need new tritium by 2005 to support a START I-size stockpile and maintain a five-year reserve of the gas. That is the Administration's current plan. If Russia ratifies START II soon, however, tritium production could be delayed until 2011 because DOE could recycle tritium from weapons that are removed from the stockpile.

The department is pursuing two methods of producing tritium: building a particle accelerator or using a commercial nuclear reactor (either buying an existing reactor or leasing space in one for DOE's special tritium-producing rods). The department intends to select one of those methods in 1998 to be its primary source of the gas. The other method will be a backup; DOE will continue to develop it for several years but not complete it.

THE BUDGETARY CONTEXT

The Department of Energy's Stockpile Stewardship and Management Program will be expensive. It is expected to cost an average of at least $4 billion a year into the foreseeable future, slightly less than average spending for similar activities during the Cold War (after accounting for inflation). The Congressional Budget Office (CBO) estimates that DOE will spend a total of $61 billion on stewardship and management from 1997 through 2010, based on the department's 1998 budget plan and its long-term estimates of spending released last year.

Can the Administration afford to keep DOE's three existing weapons laboratories at their current size and add all of the new facilities and initiatives associated with its plan for maintaining the stockpile under the CTBT? Recent emphasis on eliminating the federal deficit without raising taxes could make that difficult, at least in the near term. Affordability problems may be exacerbated if the costs of building and operating DOE's new research and production facilities exceed expectations. In addition, new regulatory arrangements could increase costs slightly.

ALTERNATIVES TO DOE'S STOCKPILE STEWARDSHIP AND MANAGEMENT PROGRAM

CBO examined four possible alternatives to the Stockpile Stewardship and Management Program to illustrate how they might affect costs. The first two would vary the number of weapons that DOE must support:

- Alternative 1 would keep the nuclear stockpile at START I levels (about 8,500 strategic warheads).

- Alternative 2 would reduce the size of the nuclear stockpile to about two-thirds below START II levels (1,000 strategic warheads).

The third and fourth options illustrate the effect of trimming the stewardship and management program:

- Alternative 3 would maintain DOE's current approach to stewardship and management but carry it out for less money by reducing the size of one weapons-design laboratory and using a commercial reactor to produce tritium.

- Alternative 4 would follow a "minimal" stewardship philosophy that places more emphasis on understanding how the nuclear primary works and replacing aging components and less emphasis on learning about the physics of secondaries. It would cancel most new facilities and focus more attention on surveillance.

The budget estimates for each alternative measure its effect on the Stockpile Stewardship and Management Program—the Administration's plan for living under START II and the CTBT. They are not intended to be estimates of the costs or savings of either treaty. Instead, the effects of the alternatives are expressed relative to the Administration's plan for DOE, which was presented in the department's 1998 budget and its estimates of spending through 2010 released last year. CBO made one change to the Administration's plan for 1998 through 2002. It added back the money required to build a tritium-producing accelerator that DOE had included in its long-term estimates but omitted from its 1998 budget.

Alternatives That Would Change the Size of the Stockpile

The future size of the U.S. nuclear stockpile is unclear. Russia has not yet ratified START II; if it does not, the United States might keep a larger stockpile. Or the United States might decide to pursue even deeper reductions, as several prominent writers and former military leaders have suggested. The first two alternatives examine possible outcomes for DOE from both of those changes.

Keeping the Stockpile at START I Levels. Alternative 1 would keep the stockpile at START I levels indefinitely, illustrating one possible outcome if Russia does not ratify the START II treaty. Although this alternative would double the size of the stockpile and the number of components that DOE would produce each year compared with the Administration's plans for START II, it would not have a large impact on costs. DOE's stewardship program would remain unchanged, because it is independent of the number of weapons in the stockpile. And the stockpile management budget would only increase by about 9 percent a year after 2002, because most of DOE's production and evaluation efforts are also independent of stockpile size. Nor would the department's plans for tritium production be affected; they already assume a START I-size stockpile.

CBO estimates that Alternative 1 would add $190 million a year to DOE's budget starting in 2003—the year when START II is supposed to be fully implemented. That amount would rise in later years to offset inflation, resulting in a total cost of $1.5 billion through 2010 (see Summary Table 1). In addition to the extra cost for DOE, the Department of Defense would have to spend about $11 billion more through 2010 to maintain its nuclear forces at START I levels. Costs would be even higher if the Defense Department decided to build new intercontinental ballistic missiles, bombers, or submarines.

Making Deep Cuts (START III). Under Alternative 2, the United States would cut its active stockpile by roughly two-thirds—from about 3,500 strategic warheads under the Administration's plans for START II to about 1,000 under an illustrative START III treaty. (The active stockpile includes all weapons that are supplied with tritium, including those that are deployed with the Department of Defense's nuclear forces and extras kept for maintenance.) Like the first option, Alternative 2 would have no effect on the stockpile stewardship budget and little effect on the production budget. Indeed, CBO estimates that cutting the production of components by two-thirds under this option would reduce costs by only $90 million a year after 2005, for a total savings of $640 million through 2010 (after adjusting for inflation).

But despite those small savings in component production, this option would save much larger sums in DOE's overall budget: $2.4 billion through 2002 and $6.5 billion through 2010 (see Summary Table 1). The reason is that deep cuts in the stockpile would allow the United States to delay building a new tritium production facility for at least 20 years. Of course, some of the savings would have to be spent after 2010 to build the facility. (Those savings are relative to CBO's estimate of DOE's stewardship and management program, which assumes that the department will build an accelerator to produce tritium. CBO makes that assumption because DOE included money for the accelerator in its most recent long-term plan. Savings from Alternative 2 would be several billion dollars less if CBO had assumed that DOE would use a commercial reactor instead.)

CBO's estimates for Alternative 2 assume that the START III treaty would be completed within the next year, the smaller arsenal would be phased in fully by 2005, and the stockpile stewardship program would be unchanged from DOE's current plans. In addition to the savings to DOE, the Defense Department could save $16 billion through 2010 by reducing its nuclear forces (assuming it kept 10 Trident submarines, 200 Minuteman missiles, and 40 B-52 bombers and did not change the size of its conventional bomber force).

Alternatives That Would Reduce the Cost of Complying with START II

Critics of DOE's approach to stockpile stewardship and management have proposed several alternatives that would reduce the scale of the program. Some would preserve the same basic philosophy but at a lower cost. Others would adopt a different philosophy: focusing less on laboratory experiments, particularly those directed at the secondary, and relying more on replacing aging components to preserve reliability.

Complying with START II for Less. Alternative 3 would do much of what DOE plans for stewardship but for less money. Accordingly, this alternative would trim the size of the stewardship program by consolidating much of the stewardship work at one design laboratory (either Los Alamos or Lawrence Livermore) and forgoing all readiness activities at the Nevada Test Site. It would also reduce costs by

SUMMARY TABLE 1. SAVINGS FROM CBO'S ALTERNATIVES (In millions of dollars)

	1997	1998	1999	2000	2001	2002	Total, 1997-2002	Total, 1997-2010
Cost of the Administration's Plan[a]								
DOE's Stewardship and Management Program	3,910	5,080	4,170	3,950	4,260	4,320	25,690	61,160
Savings from CBO's Alternatives								
1. START I Levels Retained	0	0	0	0	0	0	0	-1,520[b]
2. Deep Cuts (START III)	0	300	270	330	570	870	2,350	6,450[c,d]
3. START II for Less	0	110	400	470	740	1,050	2,760	8,440[d]
4. Minimal Stewardship	0	1,020	120	180	310	360	1,990	3,330

SOURCE: Congressional Budget Office based on data from the Department of Energy.

NOTE: DOE = Department of Energy; START = Strategic Arms Reduction Treaty.

a. CBO includes the cost of building an accelerator to produce tritium in its estimate of the cost of the Administration's plan. That cost was included in the Department of Energy's long-term plan last year but was omitted from its 1998 budget plan.

b. Because the Administration's plan assumes that START II will be ratified and U.S. forces will be reduced from current levels, Alternative 1 would raise costs for the stewardship and management program. This estimate reflects only DOE costs. Keeping U.S. forces at START I levels would also increase costs for the Department of Defense by $11 billion through 2010, assuming that the United States kept all 50 MX missiles, kept 18 Trident submarines capable of carrying D5 missiles, and did not buy any more bombers.

c. This estimate reflects only Department of Energy savings. It excludes the $16 billion that the Department of Defense might save through 2010 by reducing its forces under a START III treaty, assuming that it retained the so-called nuclear triad by deploying 200 Minuteman missiles, 10 Trident submarines, and 40 B-52 bombers.

d. The savings from Alternatives 2 and 3 assume that the Department of Energy would build an accelerator to produce tritium. Savings would be smaller compared with a baseline in which the department used a commercial reactor instead.

canceling the development of an accelerator for producing tritium and instead purchasing irradiation services from a commercial reactor.

Taken together, the changes in Alternative 3 would reduce costs by $110 million in 1998 and $2.8 billion through 2002 compared with the Administration's plan (see Summary Table 1). Through 2010, savings would total $8.4 billion. Those savings would come from three sources: partially consolidating the labs over five years starting in 1998 (saving $190 million a year after that); halting all testing and readiness activities at the Nevada Test Site by 1998 (about $70 million a year); and canceling the tritium production accelerator and buying irradiation services instead ($1.9 billion through 2002, and $5.4 billion through 2010). That last estimate assumes that DOE would have built an accelerator to produce tritium. Savings would be smaller compared with a baseline in which DOE used a commercial reactor instead.

By eliminating the independent design capability of one nuclear design laboratory, Alternative 3 would challenge DOE's contention that it must keep two independent labs to preserve the competitive atmosphere and scientific excellence necessary for conducting thorough peer review and attracting new talent. By canceling the tritium production accelerator, this alternative would use civilian nuclear reactors for military purposes—a policy that some people worry would establish a bad precedent and undermine the United States' efforts to halt the spread of nuclear weapons. In addition, Alternative 3 would end efforts to preserve the ability to resume underground nuclear testing at the Nevada Test Site within three years. Closing the test site would also limit the ability of weapons scientists to study how aging plutonium will affect reliability—a critical task for preserving the stockpile, laboratory officials say.

However, this option would provide most of the new test facilities that DOE wants (including the National Ignition Facility) and keep a cadre of weapons scientists at the second design laboratory to provide competition and peer review. Indeed, a 1995 panel commissioned by DOE concluded that adequate peer review could be maintained without a second laboratory. This option would also opt for the least costly method of producing tritium.

Changing DOE's Philosophy for Stewardship (Minimal Stewardship). Alternative 4 reflects a "minimal" stewardship approach advocated by people who argue that the existing experimental facilities and a smaller stewardship effort are all that is necessary to preserve the stockpile indefinitely. The central difference between minimal stewardship and DOE's approach lies in the tools that would be available to help weapons scientists determine the significance of age-related problems in nuclear components. DOE's approach would provide a wide array of experimental tools for that purpose. Minimal stewardship, by contrast, advances a priority-based approach in which the United States would invest only in those facilities that address the greatest needs. Advocates of minimal stewardship believe that DOE's proposed new facilities are costly and unnecessary. They are also motivated by concerns that the department's vigorous stewardship program will undermine the CTBT and other nonproliferation efforts by retaining the ability to build new types of weapons. Instead, they argue, the United States should demonstrate its commitment to the CTBT by keeping only the minimum capability necessary to preserve a reliable stockpile.

To that end, Alternative 4 would go a step beyond the partial laboratory consolidation outlined in Alternative 3 and cancel all new test facilities except the Dual-Axis Radiographic Hydrodynamic Test Facility under construction at Los Alamos. This alternative would also eliminate all testing and readiness activities at the Nevada Test Site.

This approach assumes that if age-related questions could not be answered using current facilities, DOE would build new components to replace the aging ones. As a result, nuclear components would be replaced at higher rates under Alternative 4 than DOE plans, because there would be more uncertainty about how they would be affected by age. The extent to which production would increase is not certain. But to illustrate an upper limit on what might be required, CBO assumed that production of nuclear components would rise to the level that DOE plans for a START I stockpile, twice the rate envisioned for START II. For reasons outlined in Alternative 1, increasing the production rate would boost costs only marginally (by about $100 million a year starting in 2003).

Alternative 4 would also increase funding for enhanced stockpile surveillance by 20 percent to improve further DOE's ability to detect age-related problems in the stockpile. And, consistent with the concerns about proliferation that underlie minimal stewardship, it would build an accelerator to produce tritium instead of using commercial reactors.

Alternative 4 would save $1 billion in 1998 and $2 billion through 2002 (see Summary Table 1). Through 2010, savings would total $3.3 billion. The savings would be only about 40 percent of those achieved in Alternative 3 because this alternative would build the tritium accelerator. Excluding the accelerator, savings would be about the same as in Alternative 3; the money this option would save by canceling several large experimental facilities would be offset in later years by the costs of producing a larger number of nuclear components.

Minimal stewardship is controversial, perhaps because it challenges the "science-based" stewardship philosophy around which DOE has built its plans for preserving the stockpile under a comprehensive test ban. Critics contend that minimal stewardship reduces the ability of the labs to understand the significance of problems discovered through surveillance. In the absence of underground testing, critics argue, the weapons labs must learn as much as possible about how nuclear weapons work to be able to make technical judgements about whether an age-related problem requires action. Indeed, minimal stewardship is more likely to lead to a resumption of nuclear testing, opponents contend, because the laboratories are more likely to run into a problem that will make them lose confidence in the reliability of the stockpile. Critics of minimal stewardship also believe that this alternative would not provide enough interesting work at the laboratories to attract new talent.

Supporters of minimal stewardship challenge those assertions. They argue that under their approach the United States would be able to retain confidence in its stockpile indefinitely. Nonnuclear components would be handled in exactly the same way as DOE plans, and all nuclear components would be subject to the same testing for manufacturing defects during production and assembly that DOE envisions. Furthermore, the additional funding that this option would provide for enhanced surveillance would permit scientists to detect age-related problems as early as possible.

Proponents also argue that the primary—the nuclear component that is most likely to develop problems—would receive as much attention under their approach as it would in DOE's plans. Moreover, they contend that their plan could maintain the reliability of secondaries even without building the National Ignition Facility, primarily by inspection and replacement. They also question whether the expensive new facilities that DOE proposes would be able to resolve many of the most important questions about aging weapons.

CHAPTER I

THE CHANGING POLITICAL AND MILITARY LANDSCAPE

The Department of Energy (DOE) is responsible for building, maintaining, and dismantling the United States' nuclear weapons. For that purpose, the Atomic Energy Commission developed a complex of more than a dozen major facilities throughout the country where nuclear weapons have been designed, tested, and manufactured since the 1950s. (The Department of Energy assumed responsibility for nuclear weapons in 1977.) When the Department of Energy completes weapons, it transfers them to the Department of Defense (DoD), which deploys them with the United States' long- and short-range nuclear forces. The Defense Department returns weapons to DOE for maintenance and testing, as well as for dismantling when they are retired.

The end of the Cold War has partially changed DOE's mission. The department is still responsible for certifying the reliability and safety of the nation's stockpile of nuclear weapons. But because of changes in U.S. policy, DOE is no longer actively designing or building new types of weapons. In addition, the active stockpile—the collection of all nuclear weapons that DoD deploys—is shrinking as a result of several recent unilateral and bilateral arms control measures.

Events since the Cold War have also changed how DOE maintains the nuclear stockpile. The United States declared a unilateral moratorium on underground nuclear testing in 1992 and has not conducted such tests since then. Last September, the President signed the Comprehensive Test Ban Treaty (CTBT), signifying that he intends for the United States to forgo underground testing indefinitely. (A formal commitment will not be made until the Senate ratifies the treaty.) As a result, DOE must now maintain the reliability of the nuclear stockpile over the coming decades without being able to explode weapons underground—the most straightforward and definitive method for proving that the nuclear components of a weapon work reliably.

This paper examines how DOE plans to adapt to those new realities through its Stockpile Stewardship and Management Program. How will it keep nuclear weapons operational indefinitely? How will the department's research, testing, and production facilities be affected? What will the program cost? The paper also examines some alternatives to DOE's plans that the Congress might want to consider and their possible effects.

UNILATERAL AND BILATERAL ACTIONS TO REDUCE THE NUCLEAR STOCKPILE

A flurry of formal agreements and unilateral declarations by Presidents Bush and Gorbachev in 1991 led the United States and the Soviet Union to reduce the number of weapons they deployed in both their short- and long-range nuclear forces.

Unilateral Reductions

At first, both Presidents engaged in an exchange of unilateral actions to reduce the nuclear threat in Europe and between their countries. The result was that both sides removed almost all of their short-range (or tactical) nuclear weapons from around the world.

For the United States, that included all Army battlefield nuclear weapons, many bombs carried by short-range U.S. aircraft, and all nuclear weapons on U.S. surface ships. President Bush ordered that many of those weapons be dismantled. Today, the United States keeps roughly 400 nuclear-tipped Tomahawk sea-launched cruise missiles for deployment on submarines and 600 of the Air Force's B-61 tactical bombs in the active stockpile, according to unclassified estimates.[1] (See Box 1 for a description of the active and inactive stockpiles.) That is a sharp reduction from the more than 7,500 short-range weapons that the United States reportedly deployed in 1990. The cruise missiles are now kept in the United States and are not routinely placed on Navy submarines. The B-61 tactical bombs are reportedly deployed at several locations in Europe.[2]

Bilateral Reductions

In July 1991, Presidents Bush and Gorbachev signed the first Strategic Arms Reduction Treaty (START I), which limited long-range (or strategic) nuclear missiles and bombers. It placed no limits on the number of warheads that either side can possess. The treaty was approved by the Senate in October 1992, although it did not enter into force until December 1994. Under the terms of the treaty, the United States and the Soviet Union agreed to reduce the number of "accountable" strategic

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1. Robert S. Norris and William M. Arkin, "NRDC Nuclear Notebook: U.S. Nuclear Weapons Stockpile, July 1996," *Bulletin of the Atomic Scientists* (July-August 1996), p. 63.

2. Robert S. Norris and William M. Arkin, "NRDC Nuclear Notebook: U.S. Nuclear Weapon Locations, 1995," *Bulletin of the Atomic Scientists* (November-December 1995), p. 74.

BOX 1.
THE NUCLEAR STOCKPILE

The United States keeps its stockpile of nuclear weapons in three states of readiness:

- The *active stockpile* contains all of those warheads that are supplied with tritium and ready to be deployed. (Tritium is a perishable radioactive gas that is a key ingredient in U.S. nuclear weapons.) The majority of active warheads are deployed by the Department of Defense on missiles, submarines, and bombers. Under the second Strategic Arms Reduction Treaty (START II), the United States would have about 4,500 deployed warheads, according to unclassified sources—3,500 allocated to long-range platforms and the remainder to shorter-range forces.[1] The United States also keeps a number of warheads in the active stockpile that are not deployed. In the past, those have been the small percentage of deployed warheads that are waiting to be sent to or returned from the Department of Energy for maintenance. Today, however, the United States is reported to have several thousand warheads supplied with tritium that it does not deploy. Those warheads—enough to bring the total to the START I level of around 8,500 warheads—are kept at the ready as part of the Administration's hedge against Russia's not ratifying START II.

- The *inactive stockpile* provides a reserve of backup warheads that can be used to replace warheads in the active stockpile if they become unreliable. Inactive warheads are not supplied with tritium. They can be either extra warheads of a type that will be deployed under START II or warheads of a type that will be removed from the active stockpile but could make a good substitute for deployed types. No reliable public estimates of the size of the inactive stockpile exist. However, one report estimates that it contains a few hundred warheads today and would grow by several thousand under START II as the nondeployed warheads were withdrawn from the active stockpile.[2]

- *Deactivated warheads* are those that the United States has decided to retire but has not yet dismantled. They are no longer maintained or supplied with tritium. To reduce the stockpile from Cold War levels, the Department of Energy is dismantling warheads as quickly as it can—about 1,400 each year. To date, the United States has dismantled some 10,000 warheads and plans to dismantle nearly 3,000 more over the next three years. Most of the retiring warheads are either battlefield nuclear weapons that were deployed with the Army or older strategic warheads that do not have modern safety features.

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1. Robert S. Norris and William M. Arkin, "NRDC Nuclear Notebook: U.S. Nuclear Weapons Stockpile, July 1996," *Bulletin of the Atomic Scientists* (July-August 1996), pp. 61-62.

2. Ibid.

nuclear warheads that each deployed to 6,000. (Because the treaty credited bombers with fewer warheads than they can actually hold, the real number of warheads that the United States can deploy with its long-range forces under the treaty is roughly 8,500). Both sides began cutting their forces in 1992 after the treaty entered into force and are ahead of schedule to complete their reductions by the deadline of December 2001.

The second START treaty (START II) was signed by Presidents Bush and Yeltsin on January 3, 1993. It committed both parties to reducing their strategic nuclear arsenals to between 3,000 and 3,500 deployed warheads by 2003. The United States has ratified the treaty, but its future in Russia's parliament remains uncertain. To reduce the costs of maintaining large nuclear forces, however, DoD has already started to take some of the necessary steps to comply with START II.

The Effects on DOE

Like earlier arms control agreements, neither START treaty requires the United States to dismantle warheads that are removed from their delivery vehicles as part of the treaty. As a result, the size of the active and inactive stockpiles is not directly linked to the number of warheads that are actually deployed. Nevertheless, the United States has decided to dismantle thousands of surplus warheads to cut costs and to remove old warheads that are no longer needed or do not have modern safety features.

Taken together, the START treaties, the unilateral withdrawals of short-range nuclear weapons, and U.S. efforts to dismantle warheads have shrunk the active stockpile by more than 50 percent since 1990 (from an estimated 21,000 warheads to about 10,000).[3] The number of warhead types in the active stockpile has also fallen dramatically, from more than 25 during the Cold War to about 10 today. That in turn has lowered the requirements on DOE's production complex: it will need to produce fewer components for fewer types of weapons than in the past to maintain the stockpile.

3. See Norris and Arkin, "NRDC Nuclear Notebook: U.S. Nuclear Weapons Stockpile, July 1996"; and Robert S. Norris and William M. Arkin, "NRDC Nuclear Notebook: Estimated U.S. and Soviet Russian Nuclear Stockpiles, 1945-1994," *Bulletin of the Atomic Scientists* (November-December 1994), p. 59.

SUSPENSION OF UNDERGROUND TESTING THROUGH UNILATERAL ACTION AND THE COMPREHENSIVE TEST BAN TREATY

In 1990, the Soviet Union declared a unilateral moratorium on underground nuclear testing. France followed in April 1992, and the United States responded with its own moratorium that October. Because Great Britain tests its weapons in the United States at the Nevada Test Site, it was forced to follow the U.S. lead. France lifted its moratorium temporarily (from June 1995 until January 1996) to conduct a handful of tests. China, the last of the five declared nuclear powers, did not impose its own moratorium until July 1996.

Despite erratic progress toward a moratorium on testing, all five nuclear powers committed themselves in November 1993 to negotiating a Comprehensive Test Ban Treaty at the multilateral U.N. Conference on Disarmament. The timing of those negotiations was designed to coincide with the 1995 review of the Nuclear Non-Proliferation Treaty in order to demonstrate to the world's nonnuclear states that the nuclear powers were committed to disarmament. The United Nations passed the CTBT in September 1996, but the treaty has not yet entered into force.

Past Efforts to Ban Nuclear Testing

Efforts to ban nuclear testing are not new. Since the late 1950s, a movement has existed to prohibit testing of nuclear weapons in order to halt the arms race and the spread of nuclear weapons to other countries. In 1963, prompted largely by concerns about radioactive fallout from weapons exploded in the atmosphere, the United States, Great Britain, and the Soviet Union signed the Limited Test Ban Treaty, which forbade testing nuclear weapons in the atmosphere, in space, and in the ocean. The ban was "limited" because it did allow the parties to explode nuclear weapons underground, where the fallout would largely be contained. The countries took full advantage of that method, with the United States conducting some 800 underground tests at the Nevada Test Site and the Soviet Union conducting about 500 at its own underground facilities.

In 1974, the two superpowers signed another treaty that limited nuclear testing. The Threshold Test Ban Treaty prohibited all underground testing of weapons with yields greater than 150 kilotons. (The yield is a measure of the explosive power of a weapon.)[4] For comparison, the bomb dropped on Hiroshima was about 10 times less powerful than that, and the largest weapons built by the superpowers were on the order of 100 times more powerful. The Threshold Test Ban

4. See the glossary at the end of this paper for definitions of a variety of nuclear terms.

Treaty was intended to limit the ability of either party to develop and test new weapons with yields significantly above one megaton (1,000 kilotons). Such large weapons were thought to be destabilizing because they would be the most effective in a first strike. The treaty was based on the premise that the results of tests with yields less than 150 kilotons would be difficult to apply to building megaton-sized warheads.

Neither party chose to ratify the Threshold Test Ban Treaty until 16 years later. But both sides publicly committed themselves to it and in general abided by its provisions. By most estimates, the treaty has been successful in halting the development of weapons with yields greater than one megaton.

Recent Efforts to Ban All Explosive Nuclear Tests

Recent interest in negotiating a ban on all nuclear testing has been driven more by concerns about halting the proliferation of nuclear weapons than about containing an arms race between the superpowers. In 1992, the Congress added the Hatfield Amendment to the Energy and Water Appropriations Act for Fiscal Year 1993, which halted all U.S. underground tests after September 1996. The amendment allowed DOE to conduct up to 18 more tests during the intervening four years. But the Bush Administration opted not to conduct any, and President Clinton has extended that moratorium several times. As a result, the United States has not conducted an underground test since 1992.

The Comprehensive Test Ban Treaty bans all tests in which a nuclear weapon is exploded. The United States has characterized it as a "zero-yield" test ban in which all tests that generate a nuclear yield are prohibited. In fact, the Administration's plans to conduct so-called subcritical tests, in which a very tiny yield is produced, indicate that the United States intends to treat the CTBT as a "zero-criticality" treaty. According to that interpretation, tests using plutonium will be allowed as long as they do not achieve a critical mass—that is, as long as not enough plutonium is brought together to result in a self-sustaining chain reaction.

The final fate of the CTBT has not yet been decided. India has refused to sign the treaty largely because it allows states that already have nuclear weapons to conduct vigorous research, development, and zero-yield testing programs and does not commit them to disarmament. The U.N. Conference on Disarmament, which drafted the treaty, operates by consensus and cannot approve the CTBT over India's objection. In an unusual maneuver, Australia submitted the treaty for a vote in the U.N. General Assembly, where it passed by a margin of 158 to 3 on September 10,

1996. (India, Bhutan, and Libya cast the dissenting votes.) President Clinton signed the treaty on September 24.

One final hurdle must be overcome before the treaty takes effect: the 44 nations that have nuclear weapons or nuclear reactors must ratify it. As one of those 44 countries, India will continue to block the treaty's entry into force as long as it refuses to sign. The treaty contains a provision, however, that is intended to address this problem. If not all of the 44 nations have ratified the treaty within three years, those that have may call for a review conference to take steps consistent with international law to bring the treaty into force. (However, the review conference will not have the authority to waive the requirement that all 44 states ratify the treaty.)

What that means for the United States is unclear. The Administration remains committed to the treaty and will most likely push for ratification in the Senate. The Administration will also continue to pursue its plans to preserve the nuclear stockpile without underground testing. But in the unlikely event that Russia (or perhaps China) resumes testing, the United States may abandon the treaty as well.

The Effects on DOE

The CTBT will probably have a more profound effect on the Department of Energy than reductions in the size of the stockpile because it will significantly alter the methods that the laboratories can use to certify the reliability of nuclear weapons. In anticipation of the test ban, the department is reconfiguring its weapons complex and laboratories so it will be able to maintain the U.S. stockpile indefinitely without the benefit of underground testing. In the past, if weapons scientists discovered a potentially serious age- or design-related problem with nuclear components, they could explode one or more of the weapons underground at the test site in Nevada to see whether the problem could affect the reliability or performance of the warhead. (The reliability of nonnuclear components can be measured in the laboratory without explosive testing.) In some cases, scientists also tested the repairs they made to the weapons in order to certify that the problem had been corrected. In practice, however, scientists rarely used underground tests to determine the effect of a defect on performance or reliability. The vast majority were used to develop new designs and demonstrate that newly manufactured weapons worked.

Just how DOE should preserve the nuclear stockpile under a test ban treaty has been the subject of heated debate over the past four years within the Departments of Energy and Defense, the Administration, the Congress, and nongovernmental groups. DOE has decided to pursue a "science-based" stewardship program for the stockpile that emphasizes building new test facilities to learn as much as possible about how weapons work and how age might affect their performance. DOE is also reducing the size of its production complex and restructuring operations so it can produce all the nuclear and nonnuclear components needed to maintain the seven types of weapons that are likely to remain in the active stockpile under START II. The goal is to maintain the reliability and performance of the weapons so the Defense Department can use them if necessary.

Another implication of a comprehensive test ban is that the United States is not likely to produce new types of nuclear weapons in the future. In the past, new types typically replaced older ones before the latter had reached the end of their service lives. Circumstances are different today for several reasons. First, the President has directed DOE not to develop or build any newly designed weapons (although he did instruct them to maintain the ability to do so). Second, experts believe that the United States and the other declared nuclear powers would not deploy new types of weapons under a test ban. In those experts' view, the viability of a nation's nuclear deterrent is too important to rely on a weapon design that has not been proven to work in underground tests. U.S. policy seems to be predicated on that assumption.

Nevertheless, scientists can design and build new nuclear weapons without testing. Indeed, several states in the developing world (Israel, Pakistan, and South Africa) appear to have done so without ever exploding one in a test. So why would the United States not do the same? Two reasons exist. First, the established nuclear powers would be less likely to do so because their weapons are much more complex than the first-generation weapons that most developing countries have created or could create without testing. That complexity makes it much more difficult to certify that a new type of weapon will work without testing. Of course, the United States could develop simpler weapons that were less susceptible to aging, but in the process it would have to forgo the small, lightweight warheads that allow it to deploy powerful weapons on small cruise missiles and many warheads on long-range ballistic missiles.

Second, the United States government appears to have retained much of its Cold War approach to nuclear deterrence, in which the ability to destroy large numbers of specific targets is assumed to be critical for deterring a nuclear attack. In contrast, countries like India and Pakistan seem to believe that the threat posed by a small number of weapons that in many cases have not been demonstrated and perhaps have not been assembled or deployed is still an effective deterrent.

Both the importance that the United States now places on nuclear deterrence for national security and the complexity of U.S. weapons compel the Administration to take steps to preserve the weapons that are already in the stockpile—and that will remain there for decades unless the United States decides to design and build new nuclear weapons or abolish them altogether. The Stockpile Stewardship and Management Program is DOE's answer to those challenges.

CHAPTER II

CHALLENGES IN MAINTAINING THE NUCLEAR STOCKPILE OVER THE COMING DECADES

The weapons complex lies at the heart of the Department of Energy's efforts to maintain the U.S. stockpile of nuclear weapons indefinitely. That complex includes research laboratories and the plants that manufacture and assemble the nuclear and nonnuclear materials and components required to build nuclear weapons.

DOE is responsible for certifying to the President that the nuclear weapons in the stockpile will perform correctly (that is, reliably and with the advertised yield) in the event of nuclear war. The challenge it now faces is doing so without underground testing.

THE PROBLEM OF AGING WEAPONS

The central problem for weapons scientists is that the properties of some materials in nuclear weapons change with age. In some cases, those changes can be significant enough to affect the performance of a weapon—its explosive power and reliability. Performance matters to the military because the ability of a weapon to destroy (or "hold at risk," in military parlance) certain types of targets is the cornerstone of U.S. nuclear deterrence strategy. DOE asserts that aging could also affect the safety of the weapons as well as their performance. To understand the problem that the department faces, it is helpful to understand a little about how nuclear weapons work and what they are made of.

How Modern Thermonuclear Weapons Work

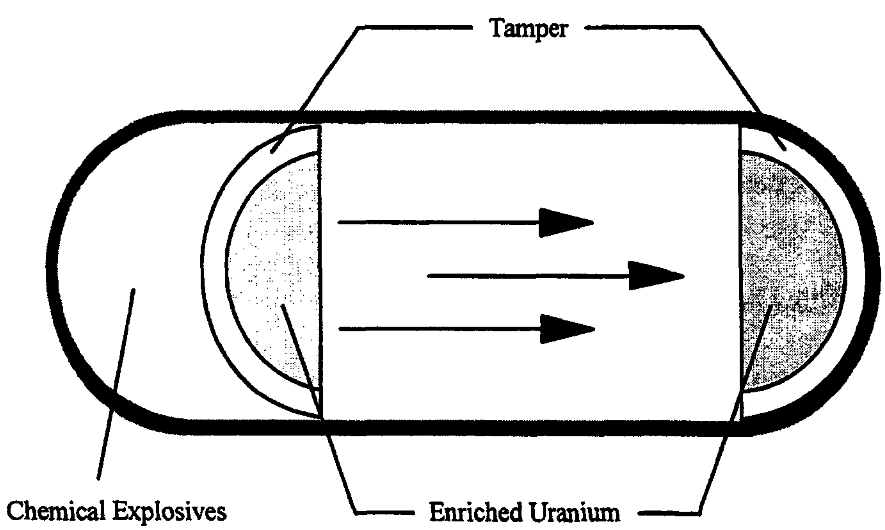
Nuclear weapons are complex devices that rely on nuclear fission and fusion to produce a high explosive yield. In a fission reaction, the large nuclei of the atoms of heavy radioactive material are bombarded by neutrons, causing them to split in half. In a fusion reaction, conversely, high heat and pressure force light atomic nuclei to combine and form heavier nuclei. Both types of reactions release atomic particles and large amounts of energy.

One of the simplest weapon designs is a gun-type fission weapon (see Figure 1). It detonates when chemical explosives force together two small masses of fissile material (a material, such as enriched uranium, that is capable of undergoing fission by itself in a rapid chain reaction). The two small masses combine to form a critical mass—a ball with enough material to sustain a nuclear chain reaction. The nuclei in the critical mass then undergo fission quickly, releasing large amounts of energy and generating a large explosion. The bomb that the United States dropped on Hiroshima was a gun-type weapon.

Over time, scientists have designed more sophisticated weapons, including those that incorporate both fission and fusion. Many modern thermonuclear weapons employ a complex fission-fusion-fission strategy to maximize the weapon's explosive yield (see Figure 2). Those weapons are sometimes referred to as hydrogen bombs or fusion bombs. The three-stage process is accomplished by a primary fission device, which produces enough energy to trigger fusion in a secondary device, and a uranium casing, which captures some of the neutrons released by the secondary to fuel a final fission reaction.

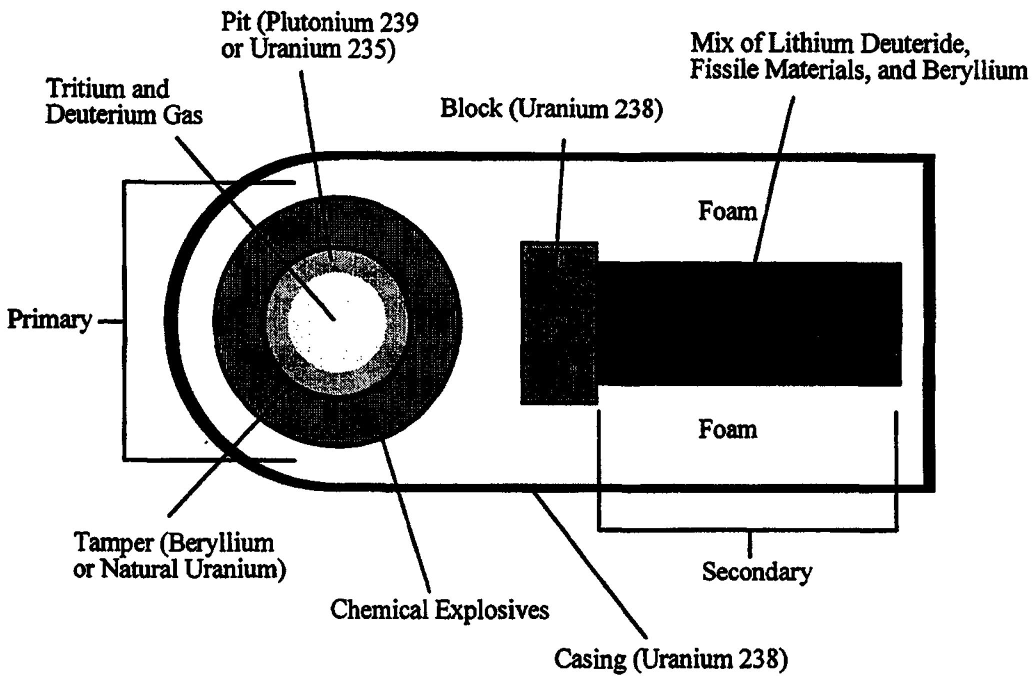
The Primary Stage: Fission Boosted by Fusion. The purpose of the primary stage of a nuclear weapon is to produce the large amounts of energy required to ignite the secondary stage. The primary, where nuclear fission first takes place, consists of high explosives surrounding a spherical shell (or pit) of plutonium or highly enriched

FIGURE 1. ILLUSTRATIVE DIAGRAM OF A GUN-TYPE FISSION WEAPON



SOURCE: Congressional Budget Office based on Dietrich Schroeer, *Science, Technology, and the Nuclear Arms Race* (New York: John Wiley and Sons, 1984), pp. 14-34, and other unclassified sources.

FIGURE 2. ILLUSTRATIVE DIAGRAM OF A THERMONUCLEAR WEAPON



SOURCE: Congressional Budget Office based on Dietrich Schroeer, *Science, Technology, and the Nuclear Arms Race* (New York: John Wiley and Sons, 1984), pp. 14-34, 62-65, and other unclassified sources.

uranium. The pit is encased in the tamper, a metal shell of beryllium or natural uranium.

To begin the explosion, an electrical charge triggers detonators, causing layers of high explosives to burn and detonate.[1] The pressure from the chemical explosives implodes the spherical metal pit to a compact shape, compressing the nuclear fissile material enough to form a critical mass. To initiate the fission reaction quickly, an initial burst of neutrons is injected, which begin splitting the heavy, unstable nuclei of plutonium or enriched uranium into smaller nuclei. In that process, a certain amount of mass is converted into energy and released in the form

1. Much of the following discussion is based on Dietrich Schroeer, *Science, Technology, and the Nuclear Arms Race* (New York: John Wiley and Sons, 1984), pp. 14-65; Department of Energy, *Final Programmatic Environmental Impact Statement for Stockpile Stewardship and Management*, vol. 1 (September 1996), p. 1-7; Howard Morland, "The H-Bomb Secret: To Know How Is to Ask Why," *The Progressive* (November 1979), pp. 14-45; and Contemporary Physics Education Project, "Two Important Fusion Reactions" (available at http://fusedweb.pppl.gov/CPEP/Chart_pages/2.TwoFusionReactions.html).

of X rays, heat, and gamma rays. In addition, neutrons and other particles are released. The released neutrons in turn split more nuclei, which releases more neutrons, and so on, resulting in a nuclear chain reaction. In the initial stages of the reaction, the beryllium or natural-uranium tamper around the pit reflects escaping neutrons back into the fissile mass.[2]

To increase the amount of energy produced without substantially increasing the weapon's size or weight, the primaries in U.S. weapons use a technique known as fusion boosting. The trick is to get as many nuclei as possible to undergo fission before the pit blows itself apart. Boosting accomplishes that by injecting a mixture of tritium and deuterium gas into the hollow center of the pit as it implodes. Under the intense heat and pressure of the ongoing fission reaction, the light nuclei of deuterium and tritium (hydrogen atoms with one and two extra neutrons, respectively) fuse together and release a fast-moving neutron. The neutrons enter the pit material and cause additional atoms to undergo fission, which increases the nuclear yield of the primary.

The net result of the fission and fusion reactions occurring in the primary stage is to produce large amounts of nuclear particles (such as neutrons) and energy (such as X rays and gamma rays). The X rays are the most essential for igniting the secondary stage of the weapon.

Thermonuclear Fusion in the Secondary Stage. The secondary stage of the weapon uses the radiation produced during the primary stage, mainly in the form of X rays, to fuse deuterium and tritium together. That reaction produces huge amounts of energy. The heart of the secondary stage is a cylindrical device that contains lithium deuteride (see Figure 2). Unclassified reports suggest that the secondary may also contain layers of fissile materials and beryllium.[3]

The secondary releases large amounts of energy through a complex process. Initially, a block of uranium shields the secondary from the shock wave created by the primary-stage explosion. Styrofoam in the area surrounding the secondary then forms a plasma and focuses the X rays from the primary onto the secondary's fusion cylinder, resulting in a radiation-induced implosion. The compressional energy, combined with a temperature exceeding that of the sun, creates the environment needed for fusion. At the same time, neutrons from the primary convert the solid

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2. Schroeer, *Science, Technology, and the Nuclear Arms Race*, pp. 14-34.

3. Kevin Cameron, "Taking Apart the Bomb," *Popular Science* (April 1993), p. 69; Morland, "The H-Bomb Secret," pp. 18-20; and Carey Sublette, "Nuclear Weapons Frequently Asked Questions: Introduction to Nuclear Weapon Physics and Design," High Energy Weapons Archive (available at http://www.pal.xgw.fi/hew/NFAQ2.HTML).

lithium deuteride into tritium and deuterium, which fuse together under the high temperatures and pressures created by the exploding primary. That reaction releases high-energy neutrons and alpha particles.

Nuclear Fission of the Uranium Casing. A third stage, made possible by a uranium casing that surrounds the primary and secondary systems, makes efficient use of the energy produced during the secondary stage. Much of the fusion energy produced by the secondary is in the form of high-energy neutrons, which tend to travel long distances and would not add significantly to the weapon's explosive yield. So designers surround the weapon with uranium 238, which has a relatively stable nucleus and generally undergoes fission only when it is bombarded by fast, high-energy neutrons. Neutrons from the secondary cause the uranium in the casing to undergo fission, significantly increasing the weapon's total yield. That final fission stage completes the thermonuclear weapon's fission-fusion-fission strategy.

How Different Components Age

Many of the materials that make up nuclear weapons change their characteristics as they age. Moreover, different materials change at different rates, sometimes over long periods of time. Because their performance is critical to the reliable performance of a weapon, DOE must be able to understand how nuclear and nonnuclear weapon components age in order to ensure the performance and reliability of the nuclear stockpile.

Nonnuclear parts such as gas reservoirs, neutron generators, electronic components, and detonators can become unreliable over time. In addition, the high explosives that are used to implode the pit can undergo slow chemical and physical changes from the heat generated by the plutonium in the pit. Fortunately, most nonnuclear components can be thoroughly tested without having to explode a nuclear weapon.

The effect of aging on one nuclear component—tritium gas—is well understood. It decays into helium 3 at a rate of about 5.5 percent a year and must be replaced at regular intervals. U.S. weapons are designed to make replacement easy.

The story for other nuclear components is not so clear. Parts of the primary and secondary can change with age but often in ways that are unknown. In addition, nuclear components cannot be fully tested without detonating the weapon.

For example, aging of the plutonium that forms the pit could affect the performance of the primary. But the way in which plutonium ages is not well understood. No weapon has been kept in the nuclear arsenal long enough for the radioactive decay of plutonium to affect performance. (The isotope of plutonium used in nuclear weapons has a half life of 24,000 years, compared with 12.3 years for tritium.) Moreover, scientists have had a very short experience with the long-lived material: it is a man-made element first produced in significant quantities in the mid-1940s. In addition, plutonium has unusual properties. For example, it can exist in six distinct phases, compared with only a few for most materials.

The issue facing weapons scientists is not that a pit's plutonium will decay in any significant quantity, but rather that the structure of the metal may change over time because of decay. There are two main concerns. First, helium gas produced by decaying atoms builds up in tiny pockets in the metal. Second, uranium atoms that are released as plutonium decays careen through the metal, knocking many plutonium atoms out of place and possibly creating voids in the metal. If either of those factors changes the structure of the plutonium enough, the pit may behave differently as it implodes. In turn, that could affect how easily the plutonium mixes with the tritium and deuterium—a key factor in the successful explosion of a primary. If too much mixing occurs, the primary may not produce enough energy to ignite the secondary and the weapon may produce only a fraction of its designed yield (less than a kiloton rather than several hundred kilotons).[4]

Concern about the interaction between plutonium and tritium during implosion is one of the consequences of the boosted primaries that U.S. weapons designers chose for all current weapons. In an effort to get the most explosive power from a weapon while making it small and light, designers reduced the amount of plutonium in the pit and used a mixture of tritium and deuterium gas to produce enough X rays to ignite the secondary. The problem is that the interactions between plutonium and gas inside an imploding pit are very complicated and not completely understood. The delicate balance of gas and plutonium necessary for a successful implosion, the uncertainty about the physics of the pit, and the crucial role the primary plays in igniting the secondary all converge to make the primary the nuclear component that DOE worries most about. A nonboosted primary with plenty of plutonium would be less susceptible to the effects of aging, but there are no such weapons in the U.S. inventory.

Aging could also affect the performance of the secondary. According to DOE, the secondary contains organic materials that can change with age and may affect performance. Further age-related problems could be introduced by the components that have been added to secondaries in some modern weapons to

4. See Frank N. von Hippel, Harold A. Feiveson, and Christopher E. Paine, "A Low-Threshold Nuclear Test Ban," *International Security*, vol. 12, no. 2 (Fall 1987), p. 144.

increase the military flexibility of the weapon through such features as selectable yields.

DOE'S ANSWER: THE STOCKPILE STEWARDSHIP AND MANAGEMENT PROGRAM

The Department of Energy plans to meet the challenge of maintaining and certifying the reliability and safety of the nuclear stockpile without exploding weapons underground through its Stockpile Stewardship and Management Program. Its stewardship effort will refocus the weapons-design laboratories on the problem of understanding the effects of aging by learning as much as possible about how nuclear weapons work. Through the stockpile management effort, DOE will watch the stockpile for signs of aging even more closely than it has in the past. The department will also reconfigure its manufacturing complex to produce more efficiently the smaller quantities of components that will be needed to maintain a relatively small stockpile under the Strategic Arms Reduction Treaties. DOE plans to spend at least $4 billion a year on stockpile stewardship and management through 2010, divided roughly evenly between the two efforts.

The Goal of Science-Based Stockpile Stewardship

Through the stockpile stewardship program, DOE's three design laboratories—Los Alamos, Lawrence Livermore, and Sandia—will get a challenging new mission. Instead of designing new weapons, they will be responsible for indefinitely maintaining the performance, reliability, and safety of the roughly 5,000 weapons of seven types that are likely to remain in the active stockpile under the START II treaty, without recourse to underground testing. In a sense, the problem they face is like trying to maintain a fleet of automobiles for several decades without being allowed to turn on the engines (or any other test engines) to make sure that they work, while at the same time ensuring that the entire fleet will start and run properly with a high degree of reliability if called upon to do so. The fact that nuclear weapons are far more complex than automobiles makes the task even more difficult.

DOE uses the term "science-based" to reflect the underlying philosophy of its stockpile stewardship program: to understand as much as possible about the physics of nuclear weapons in order to understand how aging and other problems that may occur will affect their reliability.[5] No one laboratory test can substitute completely for an underground test. At best, laboratory tests can simulate a small portion of the processes inside an exploding weapon. The strategy at DOE's laboratories is to build a number of facilities that complement each other by simulating different aspects of an exploding weapon and then use the resulting data to piece together enough information to validate computer models and thus understand problems of aging.

Surprisingly, the laboratories' quest to know as much as possible about the workings of a weapon marks a significant departure from past practices. Historically, the labs strove to understand enough about weapons physics to design new weapons and support existing designs that remained in the stockpile. However, bomb designers did not need to understand every detail about all of the processes inside a weapon to make their designs work: underground tests ultimately proved whether they worked or not. The Department of Energy argues that in the absence of underground tests, acquiring a much better knowledge of weapons physics is necessary to understand how aging will affect the weapons.

To that end, DOE plans to build several state-of-the-art facilities that will allow weapons scientists to reproduce at smaller scales some of the extreme conditions inside an exploding weapon that they have never studied closely before. The labs will use those facilities to learn more about how weapons work, how they will age, how aging will affect their performance, and how to correct age-related problems that arise through the years. Besides developing new test facilities, the stewardship program will focus on improving the computer models that simulate the interactions in an exploding nuclear weapon.

Key Stockpile Stewardship Efforts

The weapons laboratories will focus on a number of priorities under the Department of Energy's stewardship program:

- Developing new three-dimensional computer models and faster computers;
- Validating those models with data from past and future tests;

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5. For more details about DOE's stockpile stewardship program, see Department of Energy, Office of Defense Programs, *The Stockpile Stewardship and Management Program* (May 1995); Department of Energy, *Final Programmatic Environmental Impact Statement;* and Sydney Drell and others, *Science Based Stockpile Stewardship*, JASON Report JSR-94-345 (McLean, Va.: MITRE Corporation, November 1994).

- o Building the test facilities required to validate the models;
- o Conducting experiments to learn more about how weapons work and understand the effects of aging;
- o Retaining all three weapons labs to provide a vigorous research, development, and testing base;
- o Attracting new talent to the laboratories; and
- o Retaining the ability to resume underground tests with three years' notice.

Improving Computer Models. Central to the stewardship program is an effort to modernize the computer models (also called codes) that DOE used in the past as an integral part of its weapons-design work. The codes simulate on computers the complex reactions that occur in a nuclear weapon. During the Cold War, the laboratories used the codes to examine alternative designs when they were developing a new weapon. (They also conducted laboratory tests to verify a design before they would build a prototype and explode it underground at the Nevada Test Site.)

Today, the laboratories consider those codes an essential tool for preserving the reliability of the stockpile. But limitations in computing power have confined them to modeling the weapons in one or two dimensions. In other words, a sphere, which is three dimensional, is modeled as a circle. Two-dimensional codes were adequate in the past for designing new weapons, because scientists could always verify a design by testing it in Nevada. But the phenomena inside an exploding nuclear weapon are not fully represented in two-dimensional models, according to laboratory officials. In particular, such models may not adequately predict the effects of the irregularities induced by age. As a result, the Department of Energy created the Accelerated Strategic Computing Initiative to develop new three-dimensional codes and build faster computers on which to run them. The Congress appropriated $152 million for the initiative in 1997, and DOE has requested $205 million for 1998.

Validating the Models. Models are useless, however, unless they have been tested against data from actual experiments and improved until they predict the same result that experiments demonstrate. That process, called validation, is an important element of the stewardship program. The labs plan to use data from nonnuclear tests that will be conducted in the new facilities they will build over the next 10 years. They will also use data from earlier tests (both underground tests in Nevada in which weapons were actually detonated and above-ground tests at the laboratories in which certain components were tested without achieving a nuclear yield).

Building Test Facilities and Conducting Experiments. DOE believes that its existing test facilities are not adequate for the demands of stewardship in the future. Those facilities were built during the Cold War when weapon designers had the option of underground testing to prove that weapons worked. As a result, they do not produce data that is good enough to understand the effects of aging. The facilities that DOE plans to build would be able to measure results in more detail and, in some cases, would allow scientists to study aspects of nuclear weapons physics that they have not been able to study before. Those facilities are described in more detail in Chapter III.

Maintaining All Three Weapons Labs and Attracting New Talent. Under the Administration's plan, stewardship activities (as well as some stockpile management activities) would be conducted at all three of DOE's weapons laboratories: the two nuclear design labs, Los Alamos and Lawrence Livermore, and one nonnuclear design lab, Sandia, which is responsible for the myriad other components in a weapon. The two nuclear design labs are largely redundant and are intended to be so. Indeed, Livermore was created in 1952 as an independent lab that would compete with Los Alamos so designers would be motivated to develop better weapons. Having a second design lab also allows for independent peer review of weapon designs from the other laboratory. Naturally, the two developed many similar facilities. Both have so-called hydrodynamic facilities for studying the physics of primaries, facilities for studying secondaries, and facilities to build plutonium pits for weapons being tested at Nevada. Over time, however, the labs did evolve some differences. For example, Lawrence Livermore has focused more on lasers to study the physics of secondaries, whereas Los Alamos has emphasized electric pulsed-power facilities.

In 1994, the Department of Energy formed the Galvin Commission to evaluate, among other things, redundancies at the weapons laboratories. The group of independent scientists recommended that DOE seriously consider consolidation and specifically rejected the notion that a second design lab was necessary to provide independent peer review.

DOE ultimately rejected those recommendations because it believes that the independent peer review and intellectual vitality that come from vigorous competition between two labs will be essential for maintaining the reliability of the nuclear stockpile under the Comprehensive Test Ban Treaty. As the stockpile ages and the United States gets farther away from nuclear testing, independent peer review will be even more important than it was during the Cold War, the department maintains. The independent peer review team may find an age-related problem that the designers responsible for the weapon overlooked or may find alternative solutions to problems that arise.

According to DOE, a challenging intellectual environment will also serve to attract new talent to the laboratories and retain some experienced staff—one of the principal goals of the stockpile stewardship program. In fact, DOE has often used that argument as a justification for building some of its new experimental facilities, particularly the National Ignition Facility.

For all of those reasons, President Clinton has committed the Administration to retaining both nuclear design labs and the redundancy they embody. Future budgets for the laboratories probably will be about the same as they are today, and both labs will continue to keep full staffs of weapons scientists and operate some similar facilities. For example, Lawrence Livermore will retain and upgrade its own hydrodynamic test facility even though a much more capable one will be built at Los Alamos. Together, the stewardship activities at all three DOE weapons labs will cost about $1.1 billion in 1997, with spending divided almost evenly among them.

Retaining the Ability to Conduct Underground Nuclear Tests with Three Years' Notice. A final component of the stewardship program is maintaining the ability to restart testing at the Nevada Test Site if the President decides that it is in the national interest for the United States to withdraw from the CTBT. (That provision is likely to be exercised only if some critical failure renders a large portion of the stockpile unreliable or if another nation withdraws from the treaty and starts an arms race with the United States.) President Clinton has ordered that the test site be kept in a state of readiness that will make it possible to resume underground testing within three years. DOE plans to preserve readiness by conducting hydrodynamic tests there as well as so-called subcritical tests using plutonium that will allow weapons scientists to learn more about how that metal ages. The Congress appropriated $162 million in 1997 for the Nevada Test Site, and DOE has requested $157 million for 1998. The Congressional Budget Office (CBO) assumes that funding will be requested at about that level in later years. About $65 million of that amount is directly related to maintaining testing readiness, according to DOE; the remainder is spending for infrastructure and security that DOE contends would be required even if the test site was closed.

The Goal of Stockpile Management

In DOE's plan to maintain the nuclear stockpile under the Comprehensive Test Ban Treaty, management is the yin to stewardship's yang. Through stewardship, the department hopes to understand the effects that aging has on a weapon; through stockpile management, it hopes to detect components that fail with age and be able to repair them or replace them with new ones. (According to DOE, the skills and knowledge obtained through science-based stewardship will help weapons scientists determine whether a problem requires action.) Stockpile management will also be responsible for producing the components and materials that must be replaced regularly, such as tritium. The central tasks of stockpile management are:

- Closely monitoring the condition of the stockpile through enhanced surveillance;
- Replacing or repairing old components;
- Developing more durable components, if necessary;
- Maintaining the infrastructure and skilled labor to produce new components as needed;
- Producing an adequate supply of tritium by developing and building a new source; and
- Disassembling and reassembling weapons as needed.

The weapons complex has routinely performed all of those tasks in the past. It will continue to do so with a smaller complex in the future.

Enhanced Stockpile Surveillance. With weapons likely to remain in the stockpile well beyond their intended life under the test ban treaty, DOE will have to pay even closer attention to age-related problems than in the past. The department plans to spend an additional $60 million annually to develop new tests and surveillance techniques. That "enhanced surveillance" program will improve DOE's ability to monitor the condition of the stockpile and anticipate problems several years before they start to affect the reliability or performance of weapons. That program is in addition to the funds spent by the department to evaluate the condition of the stockpile; in 1997, DOE will spend about $70 million for such evaluations.

Replacing Aging Components. DOE must be able to replace aging nuclear components when surveillance of the stockpile indicates that it is necessary. The labs will also redesign some nonnuclear weapons components to improve their long-term reliability, but only those that can be fully tested without exploding a weapon. According to DOE, the United States must maintain some capability to produce, as needed, the thousands of different components for each of the seven or so types of weapons that are likely to remain in the stockpile under START II. Nuclear components include tritium, plutonium pits, and secondaries. Nonnuclear components include explosives, neutron generators, bottles to hold tritium, detonators, firing mechanisms, radars, fuzes, electronic components, plastic foam, and beryllium cases for the pits. Specialized gears, nuts, and bolts are also needed. In the past, when weapons rarely stayed in the stockpile for more than 20 years, some components were expected to last for the life of the weapon. Now, with weapons expected to last indefinitely, every weapon component will have a limited service life.

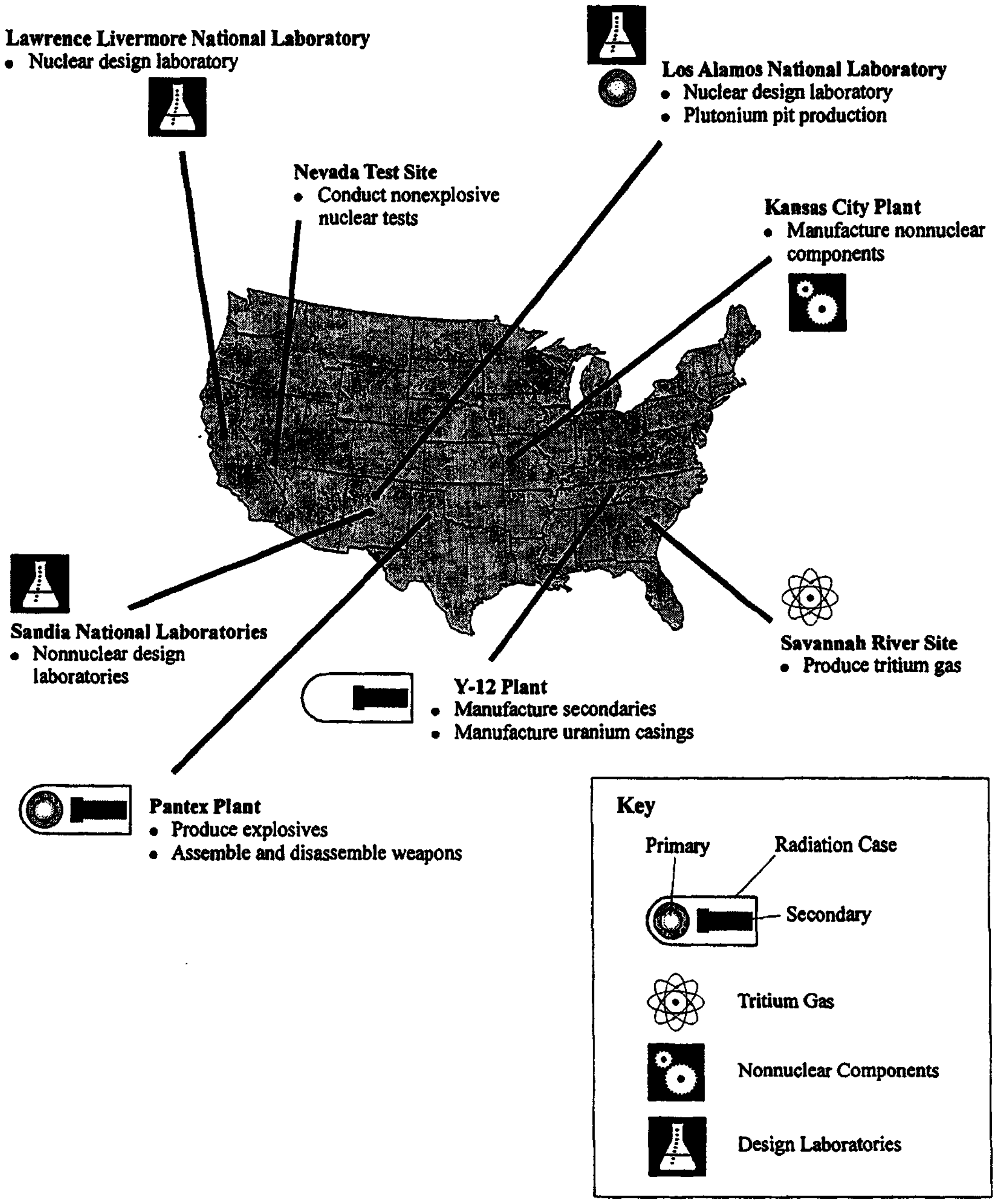
Maintaining the Infrastructure to Build New Components. During the Cold War, the Department of Energy ran a production complex with more than a dozen major facilities throughout the United States. Over the past five years, however, DOE has closed many of those facilities and consolidated production at four plants (see Figure 3).[6] It has also moved some production tasks to the design laboratories. The department is now reducing the scale of the activities at the plants, a process it calls "downsizing in place."

All nonnuclear work has been consolidated at the Kansas City Plant, except for a few components that will be manufactured at Los Alamos and Sandia. The explosives surrounding the pit will continue to be produced at the Pantex Plant outside Amarillo, Texas. DOE has divided the production of nuclear components among the remaining three plants: secondaries and uranium casings will be manufactured at the Y-12 Plant in Oak Ridge, Tennessee (no more than 50 per year); tritium will be produced at about three-sixteenths of the level projected in 1991 in either a new accelerator at the Savannah River Site or in a commercial reactor; and, after 2003, weapons will be assembled and disassembled at Pantex at a rate of about 270 a year. (Those quantities assume that START II goes into effect.) Until then, Pantex will continue to dismantle more than 1,000 weapons each year over the next few years as the United States reduces the size of its stockpile from Cold War levels. Any remanufacture or modification of pits will be done at Los Alamos at a rate of less than 50 a year under START II.

DOE has no plans to produce any more plutonium or highly enriched uranium. Indeed, it has a large surplus of both materials, which it plans to get rid of by converting them into forms not usable in nuclear weapons. Although the plutonium in the pits may change with time, DOE expects that if pits must be replaced, much of the plutonium will be reused. DOE also expects to be able to reuse many intact pits without modifying them significantly.

6. DOE has halted production at the closed facilities and transferred the responsibility for them from Defense Programs to the Environmental Management program at DOE for cleanup.

FIGURE 3. FACILITIES IN DOE'S WEAPONS COMPLEX AND THEIR PLANNED FUNCTIONS



SOURCE: Congressional Budget Office based on data from the Department of Energy.

As part of the Administration's strategy to hedge against the possibility that Russia will not ratify the START II treaty or comply with its limitations, the Department of Energy is sizing its production facilities to support a START I stockpile. If Russia does ratify START II, the department will operate those facilities at levels sufficient to support the smaller stockpile planned under the treaty. DOE will also preserve some ability to boost production above START I levels should a new arms race emerge, primarily by increasing the number of shifts each day at the facilities.

THE COSTS OF STOCKPILE STEWARDSHIP AND MANAGEMENT

The Administration plans to spend an average of more than $4 billion a year on stockpile stewardship and management from 1997 through 2010, for a total of $61 billion. Maintaining spending at that level may be difficult, however, particularly during the next five years, as the Administration and the Congress strive to balance the federal budget.

The budgetary discussion that follows reflects estimates of costs through 2010 by CBO based on data that the Department of Energy submitted to the Congress with its 1998 budget request. Readers should bear three caveats in mind. First, although the Stockpile Stewardship and Management Program assumes that the Comprehensive Test Ban Treaty and START II will go into effect, the budget projections presented here are not an estimate of the costs or savings of either treaty. Estimating the costs of those treaties requires considering many factors that are outside the scope of this analysis. Second, projecting budgets even a few years ahead always involves uncertainty; with 13-year projections, the uncertainties are that much greater. Third, the projections do not account for changes in the international situation. If Russia does not ratify START II, costs may go up as DOE increases its production levels to support a larger stockpile. If an arms race returns, the entire structure of the stewardship and management program is likely to change, and underground testing may resume. Conversely, if further cuts in the nuclear arsenal are made, the size of future budgets will be smaller.

Historical Perspective

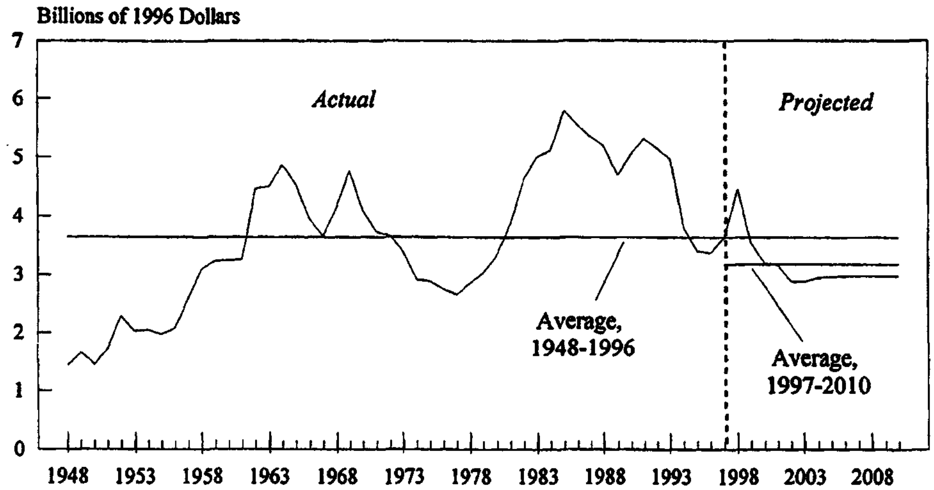
Under DOE's current plans, spending will be lower through 2010 than it was during the Reagan Administration's strategic modernization program, after accounting for inflation (see Figure 4). But on average, the United States will spend more each year on research and production of nuclear weapons, in inflation-adjusted terms, than it did throughout most of the 1950s and 1970s, and only 13 percent less than the average since 1948 (which is $3.7 billion a year in 1996 dollars).

Some supporters of DOE's plans argue that a historical comparison is misleading. Productivity per dollar is significantly lower today, they contend, because of the heavy administrative workload that is involved in frequent program reviews and in documenting compliance with environmental and safety regulations. If that is true, the laboratories and production facilities are "producing" less than a historical comparison would suggest.

Placing Stewardship and Management Spending in Context

Over the next six years, stewardship and management of the stockpile will consume only one-third of the budget for atomic energy defense activities (AEDA)—the

FIGURE 4. SPENDING ON STOCKPILE STEWARDSHIP AND MANAGEMENT, 1948-2010



SOURCE: Congressional Budget Office based on data from Stephen I. Schwartz, *Atomic Audit: The Costs and Consequences of U.S. Nuclear Weapons* (Washington, D.C.: Brookings Institution, forthcoming) for actual costs and the Department of Energy for projected costs.

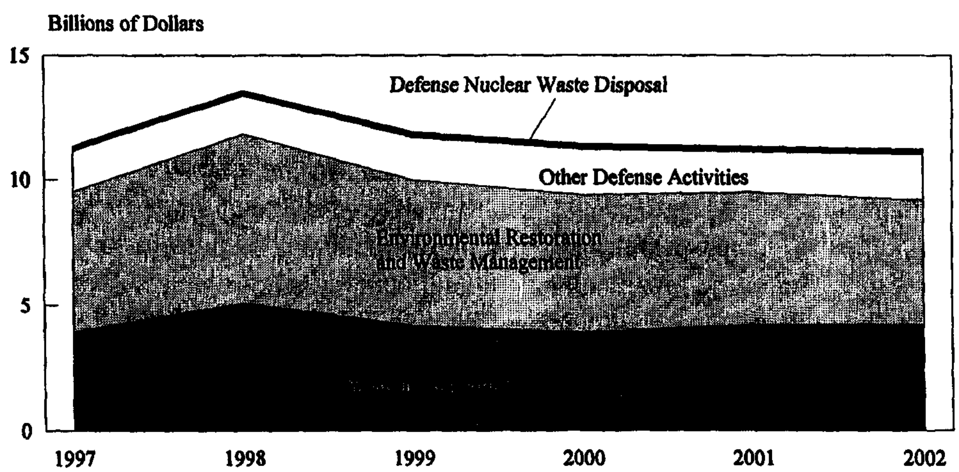
NOTE: What is now called stockpile stewardship and management was previously known as weapons research, development, testing, and production. Information about expenditures for those activities is not available for years before 1948. To allow an accurate comparison, the data in this figure exclude past funding for production of nuclear materials (plutonium and highly enriched uranium), an activity that the Department of Energy stopped in the late 1980s and does not plan to resume. The data also exclude past and projected funding for tritium production.

portion of DOE's budget allocated to all nuclear defense work. In addition to designing, manufacturing, testing, and maintaining the United States' nuclear weapons, DOE is responsible for managing and cleaning up pollution at all current and former DOE facilities. The department also designs reactors and provides technical support for the Navy's nuclear-powered ships and submarines.

In 1997, the Congress appropriated $11.4 billion for AEDA at the Department of Energy, roughly 4 percent of the $262 billion appropriated for all national defense. DOE plans to spend an average of $11.8 billion on atomic energy defense activities each year from 1997 through 2002.

The AEDA budget is dominated by two efforts: weapons activities, which include the Stockpile Stewardship and Management Program, and environmental management (see Figure 5). The latter, which includes DOE's cleanup activities, is the larger of the two; it will consume nearly half of the AEDA budget through 2002. Most of the remaining one-sixth of that budget is allocated to so-called "other defense activities." They include supporting the Navy's nuclear reactor program;

FIGURE 5. FUNDING FOR ATOMIC ENERGY DEFENSE ACTIVITIES, 1997-2002



SOURCE: Congressional Budget Office based on data from the Department of Energy.

NOTE: The peak in 1998 reflects the Administration's decision to switch from funding construction projects incrementally to paying their full cost up front.

developing technologies for verifying arms control agreements, detecting proliferation, and supporting arms control negotiations; helping Russia secure its surplus fissile materials; and other miscellaneous efforts. A tiny fraction of the AEDA budget also goes toward developing a permanent facility for disposing of DOE's high-level nuclear waste.

DOE's 1998 Budget and Long-Term Plan for Stewardship and Management

In the spring of 1996, the Department of Energy unveiled its long-term plan for maintaining the nuclear weapons stockpile as part of its budget for 1997. As in previous budgets, the 1997 plan funded construction projects incrementally—that is, the department requested money each year for ongoing projects.

In February of this year, DOE released its budget for 1998, which keeps intact virtually all of the Stockpile Stewardship and Management Program first presented in the 1997 plan. However, at the direction of the Office of Management and Budget, the department has changed its approach to budgeting for construction projects. Rather than funding such projects incrementally, it will now ask the Congress to appropriate the total amount necessary to complete a project before construction begins. DOE will then spend the money over several years as the project progresses.

Under the up-front budgeting approach, DOE's new plan for 1998 through 2002 looks different than the plan it released last year, although it supports the same program. For example, DOE added more than $1 billion in budget authority in 1998 to fully fund several projects that would have been funded incrementally under the old plan. The result is a plan that is significantly more expensive in 1998 than the incrementally funded plan but less costly in later years. However, the amount of money that the department will actually spend each year (known as outlays) will be the same under either approach because up-front funding affects only the timing of appropriations, not the size of outlays.

The only significant programmatic difference between the two plans is that DOE has omitted from the 1998 budget all of the money that it previously included for detailed engineering design and construction of the tritium production accelerator. If the department decides to build the accelerator, it will have to spend $5.4 billion, according to CBO's estimate of the construction costs, plus a further $180 million a year to operate the facility starting in 2007. The 1998 budget request did include $800 million for design and development of the accelerator. CBO included an additional $4.6 billion to address the potential shortfall for construction and another $720 million to operate the accelerator through 2010, for a total of $5.3 billion.

(Because of the high construction costs, CBO assumed that the Congress would fund the project incrementally.)

The Congressional Budget Office used DOE's 1998 budget request (plus the extra money for building the accelerator) as its baseline for measuring potential alternatives to the Stockpile Stewardship and Management Program from 1998 through 2002. For years after 2002, CBO used estimates consistent with the long-term plan that DOE released a year ago.

The Allocation of Stockpile Stewardship Funding

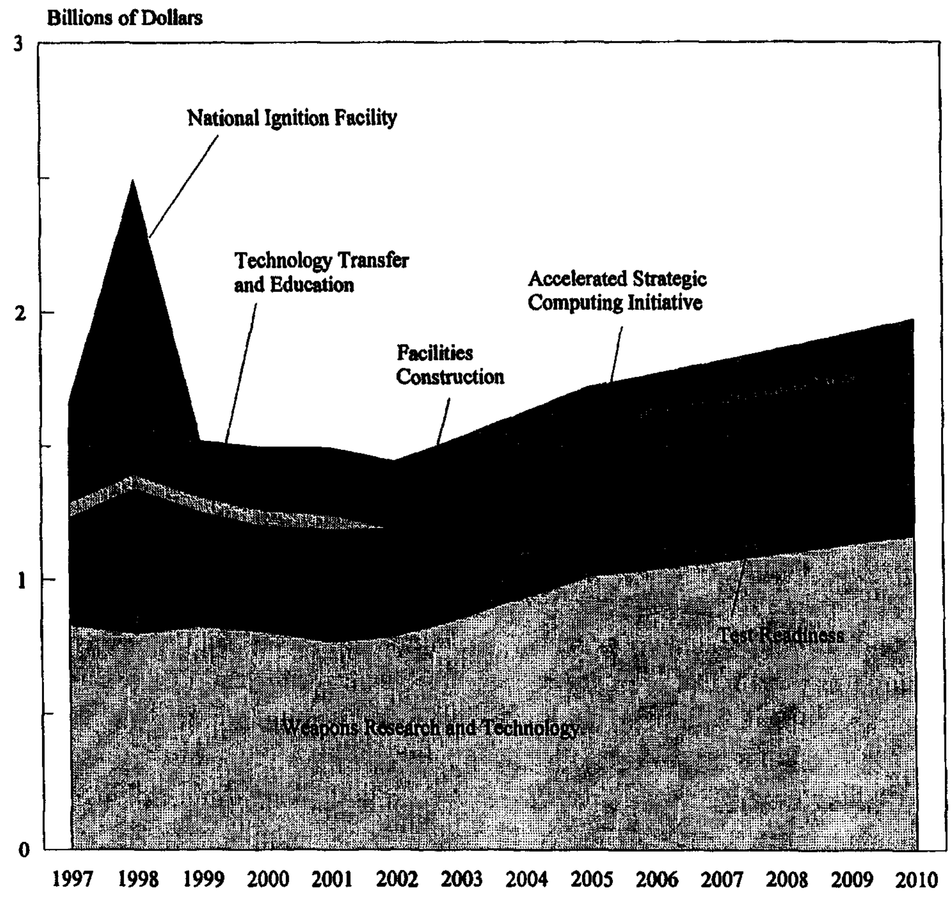
For 1997, the Congress has appropriated $1.7 billion for stockpile stewardship, meaning that effort will account for slightly more than 40 percent of DOE's weapons activities budget. Much of the stewardship money will be spent on activities at the three weapons laboratories and the Nevada Test Site. For the 1997-2002 period, the department has requested a total of $10.4 billion for stewardship. That would maintain funding at an average of $1.6 billion a year—excepting a sharp spike in 1998 to finance construction of the National Ignition Facility (see Figure 6). Funding is projected to rise at the rate of inflation after 2002.

DOE divides stewardship into three major activities. The lion's share of the budget—about $1.2 billion in 1997—will be spent on so-called core stewardship. That category funds weapons research and development at the weapons laboratories, as well as several important initiatives related to DOE's new approach to maintaining the stockpile under the CTBT. For example, ensuring the readiness to resume underground nuclear testing at the Nevada Test Site will cost about $165 million a year. The Congress appropriated $152 million for the Accelerated Strategic Computing Initiative in 1997; the Administration has requested $205 million in 1998, and CBO assumes that funding will continue at similar levels thereafter. Constructing new facilities, such as the Dual-Axis Radiographic Hydrodynamic Test Facility and the Contained Firing Facility, and making other capital improvements will cost about $90 million in 1997. Funding those projects up front will nearly double those costs in 1998, though DOE expects costs to return to nearly $100 million a year from 1999 through 2002. CBO assumes that construction and capital improvement projects will continue at those levels beyond 2002, only rising by enough to offset inflation.

DOE has proposed several other new test facilities—including the Advanced Radiation Source, Jupiter, and the High-Explosive Pulsed Power Facility—but has not yet identified funding for them in its long-term budget. A decision to build any one of those would increase the cost of the stewardship program if DOE did not reduce other activities to offset it.

The second major activity in the stewardship budget is the Inertial Confinement Fusion (ICF) program, which builds and operates lasers such as the National Ignition Facility to study the fusion processes inside a weapon. The ICF program will receive nearly $370 million in 1997, 22 percent of the stockpile stewardship budget (see Figure 7). In 1998, the Department of Energy plans to spend $1.1 billion on ICF, including $876 million in up-front financing to build the

FIGURE 6. MAJOR COMPONENTS OF THE STOCKPILE STEWARDSHIP BUDGET, 1997-2010



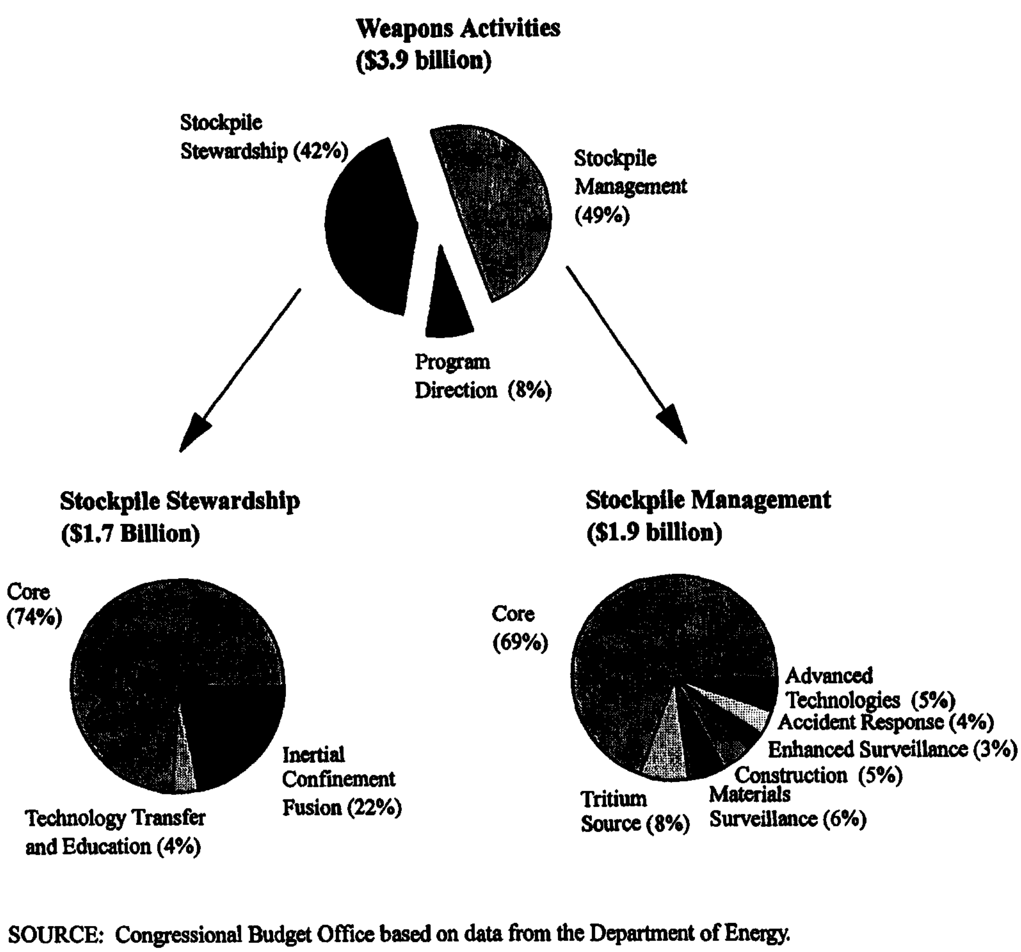
SOURCE: Congressional Budget Office based on data from the Department of Energy.

National Ignition Facility. After that, the ICF program will require more than $200 million a year, or 13 percent of stewardship funding.

The third activity in the stewardship budget, technology transfer and education, will consume $60 million a year, or 4 percent of stewardship funding in 1997. The department expects that activity to end after 2001.

The total cost of the stewardship program hinges on the size of the three design laboratories. Less than 10 percent of the stewardship budget through 2010 will be spent on building new facilities. Most of the remainder will be spent to

FIGURE 7. MAJOR COMPONENTS OF DOE'S 1997 BUDGET FOR WEAPONS ACTIVITIES



SOURCE: Congressional Budget Office based on data from the Department of Energy.

operate Los Alamos, Lawrence Livermore, and Sandia, divided about evenly between the three.

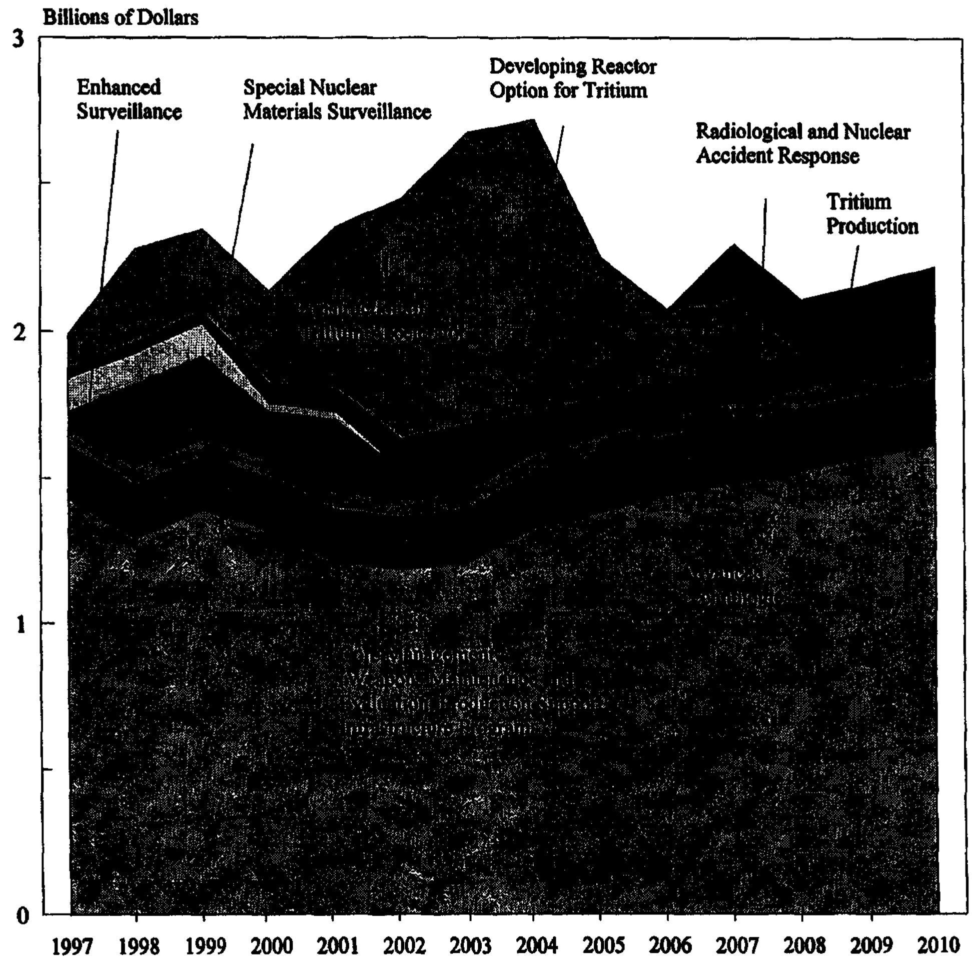
The Costs of Stockpile Management

In 1997, the Congress appropriated $1.9 billion for stockpile management—the surveillance and production activities that the department believes are necessary to preserve the reliability and performance of the weapons in the arsenal. DOE plans to spend $13.5 billion to manage the stockpile through 2002, an average of $2.3 billion a year and more than half of DOE's weapons activities budget. (That estimate assumes that the department will include money now missing from its 1998 plan to fund the construction of the tritium production accelerator.) Funding for stockpile management is expected to peak at $2.7 billion in 2003 and 2004 as the tritium accelerator is being built and fall to about $2.1 billion by 2006 (see Figure 8). In later years, funding will rise gradually at the rate of inflation.

The Department of Energy breaks its stockpile management budget into six major categories. Core stockpile management received an appropriation of more than $1.3 billion in 1997, or 69 percent of the budget (see Figure 7). The remaining 31 percent funds the development of advanced manufacturing, design, and production technologies ($101 million); the capability to respond to radiological accidents ($80 million); enhanced surveillance of the stockpile ($55 million); construction ($94 million); surveillance of special nuclear materials ($112 million); and research, development, and construction of a new tritium source ($150 million). Although building a new tritium supply is a small component of the stockpile management budget in 1997, it will consume 40 percent of the budget in 2003 before tapering off (see Figure 8). Assuming that the department chooses to produce tritium in an accelerator, operating the facility will cost $180 million a year starting in 2007, according to DOE.

Core stockpile management funds several distinct activities: weapons maintenance, evaluation, and dismantling; production support; infrastructure maintenance and improvements; and several other, small programs. The department has allocated about $260 million to maintain, evaluate, and dismantle weapons in 1997. About the same amount will be consumed by producing materials and components and supporting production, according to DOE. In addition, the department plans to spend nearly $130 million in 1997 on smaller programs such as safeguarding the transportation of nuclear weapons and materials and recycling. The bulk of that core budget, however—about $800 million, according to DOE—will be spent on maintaining and improving infrastructure. CBO projects that funding for core stockpile management will remain relatively constant through 2010, increasing only enough to offset inflation. Core stockpile management pays for most activities at the Kansas City, Pantex, Savannah River, and Y-12 facilities. It also finances the production and surveillance activities now being performed at the weapons labs, most of which were added when DOE consolidated the production complex.

FIGURE 8. MAJOR COMPONENTS OF THE STOCKPILE MANAGEMENT BUDGET, 1997-2010



SOURCE: Congressional Budget Office based on data from the Department of Energy.

NOTE: The budget that DOE recently released for the 1998-2002 period omits funding for building the accelerator that it had included in its plan released just one year ago. Since DOE's long-term plan assumes that the accelerator will be built, CBO has restored the funding. See the discussion of the costs of the Administration's plan in Chapter II for more details.

The cost of stockpile management depends on the size and nature of the production complex and the scope of the stockpile surveillance program. The most significant variable in the near term is DOE's decision about how to produce tritium (discussed in more detail in the next chapter). The department's long-term plan assumes for budgeting purposes that DOE will opt for an accelerator. If DOE chooses a less expensive method, such as purchasing its own commercial reactor or buying irradiation services from a reactor owned by a utility, the costs of stockpile management could fall by several billion dollars through 2010.

The size of the nuclear stockpile will also have some bearing on the size of the stockpile management budget. Because most costs of stockpile management are fixed, the budget does not vary much with the number of warheads in the stockpile. But if the size of the stockpile was reduced as a result of unilateral or bilateral arms control measures, the need to produce tritium could be delayed for years, and a new source of tritium could be smaller and cheaper to build and operate. Other production activities might also be scaled back, since fewer warheads would mean fewer components that would need to be replaced. Conversely, if the United States increased the size of the stockpile or did not reduce it from today's level to that anticipated under START II, production costs could be higher.

Program Direction

The Department of Energy plans to allocate about $300 million each year for directing the Stockpile Stewardship and Management Program at its headquarters and operations offices. That accounts for less than 10 percent of annual spending on weapons activities. The department intends to maintain funding for program direction at that level without adjustments for inflation by continually improving the efficiency with which it manages the weapons activities.

Factors Not Considered in This Analysis

CBO's projection of the costs of the Administration's plan for DOE excludes several important factors. First, the costs of building new facilities could exceed current estimates. In the past, DOE has experienced cost increases for a number of facilities built under its weapons program. Some of the facilities that are now planned will push the state of the art, and new technologies frequently cost more than originally estimated. Moreover, unanticipated regulatory constraints could force expensive changes. However, the Department of Energy has completed several facilities at or below projected costs, and similar outcomes are possible for its new projects.

For most of the planned facilities, higher-than-expected or lower-than-expected costs would not have a significant effect on the affordability of the Stockpile Stewardship and Management Program. The expected price tags of those facilities do not exceed $100 million each, and cost overruns would be spread over several years. Nevertheless, unanticipated cost increases or decreases for the larger facilities, such as the National Ignition Facility and the tritium production accelerator, would have a measurable effect.

Second, this analysis does not address possible costs for cleaning up those new facilities after they have been shut down. In its cost estimates for most of the new facilities, DOE did not include money to decontaminate and decommission them at the end of their service lives. The department argues that most of the experimental facilities for the stewardship program and the tritium production accelerator will not entail any decontamination and decommissioning costs because they will not contaminate the areas around them. Critics contend that such a belief is unrealistic. At the very least, operating the facilities over time will produce chemical wastes such as capacitor oils, solvents, and so forth, they argue. Furthermore, some of the materials that simulate pits in hydrodynamic test facilities can harm the environment. Because most of the facilities are expected to last for at least 30 years, any bills for decontamination and decommissioning will not come due until well beyond the 2010 horizon of this analysis.

A final factor not considered here is the effect on DOE as it transfers regulatory responsibility for all of its nuclear facilities, including accelerators, to the Nuclear Regulatory Commission. That process will take about a decade. The precise implications for the department are not yet known, but costs are expected to rise slightly as DOE takes steps to meet the commission's more rigorous safety requirements.

CHAPTER III

BUILDING NEW FACILITIES

FOR STEWARDSHIP AND MANAGEMENT

The Department of Energy will embark on a series of projects through the next decade that will help its scientists and engineers maintain the performance, reliability, and safety of the nuclear stockpile under the Comprehensive Test Ban Treaty. It also plans to reconfigure its production complex in order to produce the components and tritium that those nuclear weapons will require.

NEW EXPERIMENTAL FACILITIES FOR STEWARDSHIP

DOE's plans call for building several new facilities at its three weapons laboratories over the next decade. Those facilities will allow weapons scientists to learn more about the processes that take place inside an exploding nuclear weapon without actually having to explode one. Some of the facilities will focus on the primary, the fission bomb that ignites the fusion secondary. Others will focus on the secondary. Using data from tests done over the next 10 to 15 years, as well as data from past laboratory tests and underground nuclear tests, the labs plan to validate the three-dimensional computer codes they are developing. They can then use those codes and further tests to explore the effects of age-related problems on the performance, reliability, and safety of the weapons. Some facilities will also be used to study the effects of radiation on the components of nuclear weapons and of other Defense Department weapons and satellites. Finally, DOE will build a new facility at the Sandia National Laboratories to help scientists design new components and explore new production technologies.

Although the new facilities are central to DOE's plans for stockpile stewardship, they will account for less than 10 percent of the stewardship budget through 2010. The lion's share of that budget is allocated to pay for the people at the three weapons labs who work on stewardship.

Facilities That Focus on the Primary

One of the laboratories' most important efforts will be to understand the workings of the exploding pit in the nuclear primary. The primary is one of the most critical parts of a weapon: if it does not work properly, the fusion reaction in the secondary is unlikely to occur and the weapon will explode with only a fraction of its expected power. The primary is also one of the most complex components of a weapon.

Several systems must function properly to within millionths of a second for it to generate enough X rays to ignite the secondary. Because of the importance and complexity of primaries, the stewardship program will invest at least several hundred million dollars to develop new test facilities to learn more about how they operate.

Using new and existing hydrodynamic testing facilities, the laboratories hope to learn more about how the pit implodes and how plutonium mixes with tritium in a normal weapon. Another area of interest is how changes in the structure of the plutonium metal would affect that mixing. In hydrodynamic tests, scientists implode a pit made of a nonfissile material that simulates the properties of plutonium and take X-ray "snapshots" during the implosion with high-speed X-ray machines to see what is going on inside the pit. (The tests are called "hydrodynamic" because the hot plutonium behaves like a fluid.)

The Department of Energy intends to have five hydrodynamic test facilities in all. It will continue using two facilities at the Nevada Test Site and will build two new ones and upgrade another at the national laboratories. The first new facility, called the Dual-Axis Radiographic Hydrodynamic Test (DARHT) Facility, is under construction at Los Alamos. When operations begin in 1999, it will provide better-quality data than any existing facility. The other new facility, the Advanced Hydrodynamic Test (AHT) Facility, will provide even better data when it becomes operational in 2004. Although that facility is not part of DOE's five-year budget, it is included in the department's long-term plans for stockpile stewardship.

Dual-Axis Radiographic Hydrodynamic Test Facility. When it is completed, DARHT will be the first hydrodynamic test facility to take X-ray pictures of an imploding pit from two directions (axes) at once or in rapid sequence. The powerful X-ray generator will also produce images with better spatial resolution than existing facilities can. Using those images, weapons scientists will be able to construct a three-dimensional picture of the internal dynamics of a pit, which they say is essential to understanding how age-related imperfections in a pit could affect the performance of the primary. DARHT will be more capable than the existing Pulsed High Energy Machine Emitting X rays (PHERMEX) facility at Los Alamos.

Construction on DARHT began in 1989 but was halted in 1995 by a lawsuit that challenged DOE's estimates of the environmental impact of the facility. DOE resumed construction in May 1996, and it expects to have the first axis of DARHT operational in 1999. The second axis should be working by 2002, according to preliminary plans. Altogether, the facility will cost $199 million to build, according to the department. About $110 million of that remains to be spent (see Table 1).

After that, DOE expects to spend at least $10 million each year to operate the facility throughout its projected 30-year service life.

The Advanced Hydrodynamic Test Facility. The AHT facility would provide much better information about what happens inside an imploding pit by taking X-ray pictures from as many as eight directions and taking as many as 20 snapshots per

TABLE 1. COSTS OF BUILDING DOE'S NEW STEWARDSHIP FACILITIES (In millions of dollars)

Facility	Prior Years	1997	1998	1999	2000	2001	2002	Total Construction Cost	Annual Operating Cost
New Facilities That Focus on the Primary									
Dual-Axis Radiographic Hydrodynamic Test Facility (DARHT)	87	4	47	60	1	0	0	199	10
Advanced Hydro-dynamic Test Facility	0	0	0	0	25	125	140	440	10
Contained Firing Facility	9	17	26	1	0	0	0	53	6
New Facilities That Focus on the Secondary									
National Ignition Facility (NIF)	79	191	908	7	14	0	0	1,199	116
Atlas Pulsed-Power Facility	13	16	21	0	0	0	0	49	4
New Facilities That Focus on Weapons Effects									
Advanced Radiation Source	0	0	0	0	0	0	0	350	50
New Facilities That Focus on Developing Manufacturing Processes									
Process and Environ-mental Technology Laboratory	3	15	30	0	0	0	0	49	59

SOURCE: Congressional Budget Office based on data from the Department of Energy.

test. DOE is still exploring the best design for the facility. According to the department's preliminary estimates, work would begin in 2000 and conclude in 2004, at a total cost of $440 million. No estimates of operating costs are available yet, but they would probably not be any lower than those of DARHT, which DOE estimates at $10 million a year. DOE has not yet selected a location for the AHT, although the main candidates are the Nevada Test Site and Los Alamos.

Contained Firing Facility Upgrade. DOE plans to upgrade the hydrodynamic test facility at Lawrence Livermore (now called the Flash X-ray Facility) over the next three years by enclosing the area where the explosions take place. The resulting Contained Firing Facility (CFF) is primarily intended to address the environmental, safety, and health issues raised by current uncontained operations. In addition, it will allow experiments to be conducted in a more controlled environment. However, the CFF's capability will not approach that of DARHT. Instead, the facility will allow hydrodynamic testing to continue at Lawrence Livermore. DOE argues that such redundancy is necessary to keep an independent design laboratory at Livermore and attract primary designers to it. Construction on the CFF will start this year and finish by the end of 1999 at a cost of $53 million, according to the department. Operating the facility will cost nearly $6 million a year over its projected 40-year life.

Existing Facilities at the Nevada Test Site. The laboratories will continue to use two existing facilities at the Nevada Test Site: the Lyner Facility (whose name stands for low-yield nuclear test and research) and the Big Explosives Experimental Facility (also known as BEEF). Although they do not produce the high-resolution data of DARHT and the CFF, those facilities allow scientists to perform certain hydrodynamic and other tests they could not conduct in the populated environments of the weapons labs. At the Lyner Facility, for example, experiments are done 1,000 feet underground in what is essentially a mine. Scientists can set up simulated pits in short tunnels off the main shaft, seal them with earth, and then detonate the pits.

DOE established the Lyner Facility a few years ago in anticipation of the Comprehensive Test Ban Treaty so the labs could conduct very low yield nuclear tests (sometimes called hydronuclear tests). The idea was that the tunnels would contain the radiation and radioactive materials from those experiments. In August 1995, however, President Clinton declared that the United States would adhere to a "zero-yield" testing policy that prohibited hydronuclear tests and would encourage the Conference on Disarmament to negotiate a "zero-yield" comprehensive test ban.[1]

1. The term "zero-yield" is something of a misnomer; "zero-criticality" is more accurate. The United States will allow the laboratories to conduct hydrodynamic tests using plutonium in which a tiny amount of yield will inevitably be produced. However, such tests will be designed so that the plutonium never reaches a critical mass and undergoes a self-sustaining chain reaction.

At the same time, he directed DOE to preserve the infrastructure and skilled technicians necessary to resume large-scale underground nuclear tests with three years' notice.

The Department of Energy has determined that conducting hydrodynamic and other tests at the Lyner Facility is the best way to retain enough skilled personnel at the Nevada Test Site to meet the President's readiness requirement. Data from Lyner will not be multidimensional, nor will they have as high a resolution as data from other existing or planned hydrodynamic test facilities. But besides preserving readiness at the Nevada Test Site, the Lyner Facility will enable scientists to conduct "subcritical" experiments with plutonium that will allow them to study how the metal's behavior changes as it ages. Those experiments are considered essential by the laboratories and are more difficult and expensive to conduct safely in an aboveground facility such as DARHT.

The labs will also conduct tests at Nevada's Big Explosives Experimental Facility to study the hydrodynamic motion associated with detonations of high explosives when the tests call for more explosives than can be used safely at the laboratories. That facility may also be used for very large explosive pulsed-power generators (see the discussion on page 43). It lacks equipment to produce high-resolution X-ray images, however.

In all, the Department of Energy plans to spend $165 million a year to keep the Nevada Test Site operational, about $65 million of which is directly related to maintaining testing readiness, including activities at the Lyner Facility. The remaining $100 million will pay for the security and infrastructure that DOE says would be required at the test site even if all testing readiness activities were halted.

Facilities That Focus on the Secondary

DOE plans to spend nearly twice as much on building facilities to study the fusion processes that take place in a weapon's secondary as it will spend on facilities dedicated to primaries (see Table 1). Many experts believe that a secondary is less susceptible to problems of aging than a boosted primary—provided, of course, that it receives enough X rays from the primary to ignite the fusion reaction. But DOE believes that it should study the effects of age-related changes and other defects by reproducing, to the greatest extent possible, the extreme pressure and temperature conditions within an exploding secondary. The new facilities can also be used to study the fusion that occurs in boosted primaries.

The National Ignition Facility. The most expensive of all of DOE's new stewardship facilities is the National Ignition Facility (NIF) at Lawrence Livermore, which will use 192 lasers to heat and compress tiny pellets of fuel enough to cause a fusion reaction. NIF will create conditions very close to some of those found in an exploding secondary. It will permit weapons scientists to study the "opacity" of a material (the way radiation is transmitted through matter at very high temperatures and pressures) and how opacity may change with defects in the secondary or in the uranium bomb casing that reflects radiation from the primary onto the secondary. Supporters of NIF also contend that it will allow them to learn more about the physics of tritium boosting in the primary and the mixing of materials in the secondary. In addition, X rays, neutrons, and gamma rays produced by NIF can be used to test how radiation from nuclear weapons affects the performance of bomb components of nuclear and nonnuclear weapon systems—a class of tests called weapons-effects experiments.[2]

DOE argues that a state-of-the-art scientific facility like NIF will not only produce important data but also be essential in continuing to attract talented young scientists to the stewardship program. NIF will not duplicate the capability of other existing or planned facilities because it will be the only test site able to create the very high temperature and pressure conditions needed to study the fusion processes that occur within an actual weapon.

Officials at Lawrence Livermore say data from the National Ignition Facility will help scientists understand how age-related defects such as oxidation cracks can affect the performance of nuclear weapons. Perhaps most important, the data from NIF will help them validate the three-dimensional codes they are developing as part of the stockpile stewardship program.

All of that capability comes with a large price tag. At $1.2 billion, according to DOE, the National Ignition Facility will cost two-and-a-half times more to develop and build than any other new test facility (see Table 1). The department estimates that NIF will cost another $116 million a year to run after it becomes fully operational in 2003.

The National Ignition Facility is a controversial program. The JASONs, an independent group of scientists that the government sometimes asks to review technical programs, agree with DOE's contention that studying secondaries is important and that NIF is a key element of the stewardship program—for its ability

2. For more about the possible uses of NIF, see Richard E. Rowberg, *The National Ignition Facility and Stockpile Stewardship*, CRS Report for Congress 97-337 SPR (Congressional Research Service, March 11, 1997).

both to probe the fusion process and to attract young scientists to the weapons labs.[3] Other experts disagree, arguing that secondaries are stable enough and well enough understood that a facility as expensive as NIF is unnecessary.[4] Furthermore, they contend, NIF may send the wrong signal to the nonnuclear countries that the United States is urging to support the Comprehensive Test Ban Treaty. Indeed, India cites the United States' robust stewardship program, which includes NIF, as one of its primary objections to the treaty. According to India, the computer simulations and experimental facilities will allow the United States to circumvent the intent of the test ban.

The Atlas Pulsed-Power Facility. Besides studying weapons physics by using lasers to ionize targets (as in the National Ignition Facility), DOE uses pulsed-power facilities, in which huge amounts of electricity are applied to a target very rapidly. The advantage of pulsed-power facilities is that they can accommodate targets large enough to study centimeter-sized defects in materials of the sort that might occur from aging or during remanufacturing. The disadvantage is that pulsed power cannot come as close as lasers to approximating the high temperatures and pressures inside an exploding weapon.

DOE plans to build a second pulsed-power facility at Los Alamos, known as Atlas, because the existing facility (Pegasus II) is not powerful enough for all of the experiments that weapons scientists want to conduct under the stewardship program. DOE expects to begin construction of Atlas this year and start operations by 2000. According to the department, the facility will cost $49 million to build and roughly $4 million a year to operate.

The High-Explosive Pulsed Power Facility. To complement the Atlas and Pegasus pulsed-power facilities, DOE also plans to build the High-Explosive Pulsed Power Facility at the Nevada Test Site. As its name suggests, that facility will employ high explosives to produce large pulses of electricity that will, in turn, create the magnetic fields used to compress targets in studying the physics of secondaries. According to DOE, high explosives are by far the most efficient way to create shock pressures and velocities close to those found in an exploding nuclear weapon; the cost of building an electrical pulsed-power machine that could create the same conditions would be prohibitive. The facility will be used to study larger-scale defects than are possible

3. See Sydney Drell and others, *Science Based Stockpile Stewardship,* JASON Report JSR-94-345 (McLean, Va.: MITRE Corporation, November 1994); and David Hammer and others, *Inertial Confinement Fusion (ICF) Review,* JASON Report JSR-96-300 (McLean, Va.: MITRE Corporation, March 1996).

4. Tom Zamora Collina, "The National Ignition Facility: Buyer Beware," *Technology Review* (February/March 1997), pp. 34-40.

with Atlas or NIF. The project is too early in the design phase for DOE to have firm cost estimates.

Facilities That Focus on Weapons Effects

Part of DOE's mission is to study the effects of nuclear weapons on bomb components and other military hardware. Without access to actual nuclear explosions, DOE must rely on laboratory facilities to study the effects of radiation such as X rays. Scientists now use the Saturn and Particle Beam Fusion Accelerator pulsed-power X-ray facilities at Sandia for that purpose. The National Ignition Facility at Lawrence Livermore will also have some capability to study weapons effects. But DOE believes that it may need a new facility to produce certain radiation environments at scales large enough that they could otherwise be found only in underground tests. It plans to begin building the Advanced Radiation Source at Sandia sometime after 2002. Preliminary estimates by Sandia indicate that construction costs would be on the order of $350 million (see Table 1). Operating costs for the facility would be about $50 million a year, according to laboratory officials. DOE has also considered building a more capable successor to Saturn, called Jupiter, but that project has been delayed indefinitely.

Facilities That Focus on Developing Manufacturing Processes

DOE plans to construct a new facility at Sandia related to stockpile surveillance and manufacturing processes. The Process and Environmental Technology Laboratory (PETL) would be used to develop advanced stockpile surveillance technologies, evaluate age-related defects found during surveillance, and develop efficient technologies for manufacturing replacement parts. The laboratory will replace several existing facilities at Sandia, in part because DOE estimates that it will be less expensive than upgrading those facilities to meet current environmental and safety standards. The department estimates that PETL will cost $49 million to build and will start operating by 2001 at a cost of nearly $60 million a year (see Table 1).

NEW PRODUCTION FACILITIES FOR STOCKPILE MANAGEMENT

The Department of Energy has completed most of its planned consolidation of the weapons production complex. But it has not yet begun construction of two important facilities: a tritium source and a pit remanufacturing plant.

Developing a Source of Tritium

The most immediate decision facing DOE involves building a source of tritium to replace what is lost through radioactive decay. Tritium is a radioactive gas that is stored in bottles in nuclear warheads. When injected into the pit, it boosts the efficiency of the fission reaction there. Scientists generally produce tritium by bombarding targets made of lithium with neutrons in nuclear reactors, where the fissioning of the uranium fuel produces lots of neutrons. More recently, scientists have produced small quantities of tritium in a particle accelerator by bombarding helium 3 gas with neutrons. DOE used reactors at Savannah River to produce tritium until 1988, when the last one was shut down because of concerns about safety. The reactor is not likely to be restarted. As a result, the United States has no source of tritium in operation and no facility that could be started immediately.

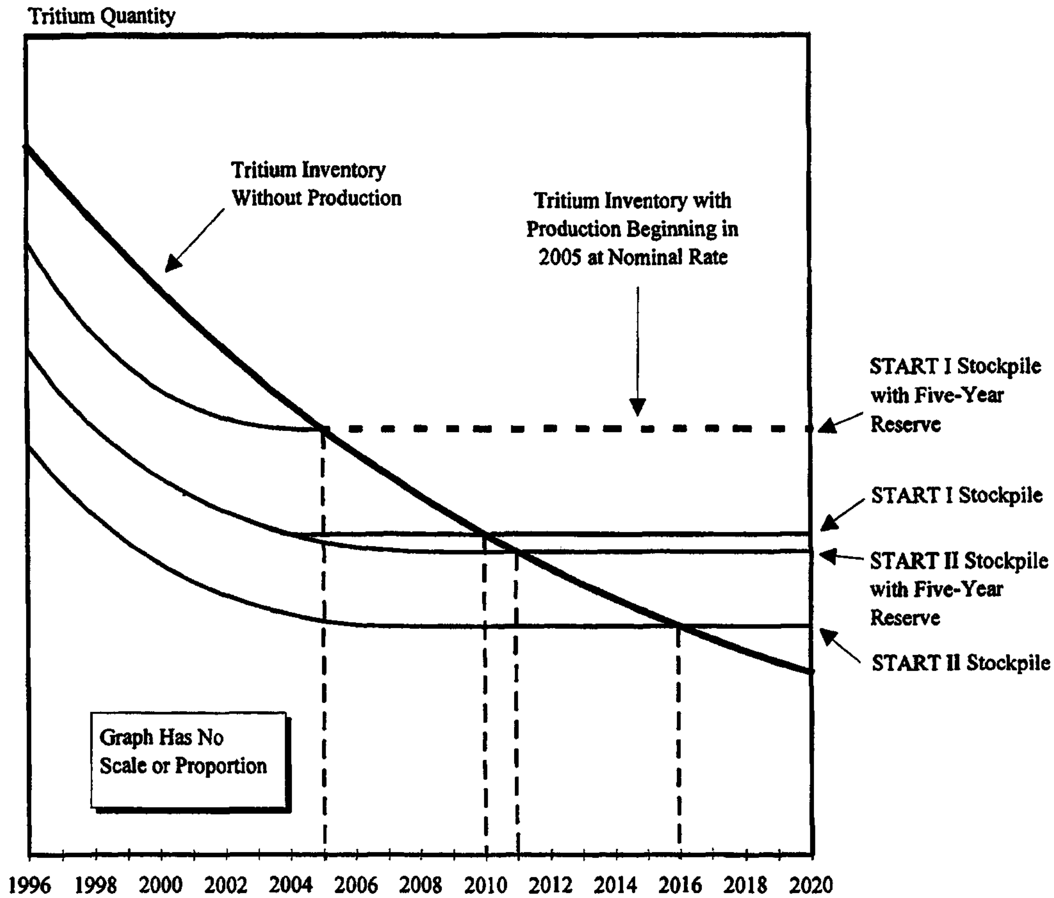
So far, the hiatus in tritium production has not been a problem because it has coincided with a period in which the United States and Russia have been reducing the number of weapons in their arsenals after the Cold War. Those reductions have allowed DOE to remove the tritium from weapons that are being retired from the active stockpile and use it to replace the spent tritium in the remaining weapons. If Russia ratifies the START II treaty and the United States reduces its active stockpile to START II levels by 2003, DOE will not need to produce new tritium until 2011. It will have enough to supply the remaining warheads until then and keep a five-year reserve to guard against any unexpected losses or breaks in future production.

Whether the Russian legislature will ratify the treaty is uncertain, however. The Administration's response to that uncertainty is to hedge its bets by retaining an active nuclear stockpile much closer to START I levels than START II levels. Doing so allows the United States to redeploy those warheads quickly if necessary.

As long as the hedge policy remains in effect, DOE will require tritium sooner than needed under START II. Supplying tritium to a START I-size stockpile and maintaining the corresponding five-year reserve means DOE will need to begin producing the gas as early as 2005 (see Figure 9). The Nuclear Weapons Stockpile Memorandum for 1996, which established the government's stockpile requirements for that year, mandated that DOE fashion its tritium policy so it has a high probability of meeting that objective.[5] The Administration has determined that DOE must be able to produce at least 2 kilograms of the gas each year at nominal production rates and that the new production facility must be able to increase production by 50 percent (to 3 kilograms a year) within three years of a decision to

5. Clifford Lau and Richard E. Rowberg, *The Department of Energy's Tritium Production Program*, CRS Issue Brief IB-97002 (Congressional Research Service, March 11, 1997).

FIGURE 9. TRITIUM REQUIREMENTS FOR THE NUCLEAR WEAPONS STOCKPILE



SOURCE: Department of Energy, Tritium Project Office, "Status Briefing," June 25, 1996, and Department of Energy, "Tritium Production Capability Program," in *Stockpile Stewardship and Management Plan* (February 29, 1996), Chapter VI.

do so.[6] That would allow DOE to restore the tritium supply within five years if, for some reason, the reserve was destroyed. Being able to boost production to 3 kilograms a year would also allow DOE to support a stockpile that exceeded START I levels, if necessary.

To satisfy those requirements, DOE plans to be able to produce tritium at the rate of 2 kilograms a year by 2005. It will also upgrade its tritium recycling facility,

6. Department of Energy, "Tritium Production Capability Program," in *Stockpile Stewardship and Management Plan* (February 29, 1996), Chapter VI.

where new tritium is added to the tritium recycled from retired warheads before being placed in warheads in the active stockpile.

DOE has decided that it will pursue two parallel approaches to producing tritium: a commercial nuclear reactor and a linear accelerator. At the end of 1998, the department will select one of those approaches to be its primary tritium source. To make sure that it has a backup in case the selected approach does not work as planned, DOE will continue developing the other approach (if it is proven to be feasible) for several more years until the backup technology has been demonstrated. At that point, work on the backup approach will cease.

Although the department has kept to its dual-path approach, the Secretary of Energy added a new wrinkle in December 1996 when she stopped the Fast Flux Test Facility in Idaho from being decommissioned. She made the decision to preserve the reactor at that site as a third option for producing tritium in case the other two experience difficulties or requirements for production change.

Commercial Light-Water Reactor. In a break with tradition, DOE has decided that under the first approach it would not build its own nuclear reactor to produce tritium. Instead, it would use a commercial light-water reactor—either buying one that is now in operation or near completion from a utility, or leasing space in commercial reactors whose primary mission would continue to be producing electricity for the utilities that own them.[7] DOE plans to choose between those options by the end of 1998. The Secretary of Energy will then compare the reactor option selected with a linear accelerator to decide which technology DOE should use for producing tritium.

If the department purchased a commercial reactor, it would replace some of the so-called burnable poison rods in the fuel assemblies, which absorb excess neutrons, with target rods. Once inside the reactor, the target rods would absorb neutrons and produce tritium. Every year or two, the targets would be removed and sent to a new extraction facility that DOE is building at the Savannah River Site in South Carolina; there, the tritium would be removed from the rods. DOE would sell the electricity that the reactor generated to the public. (The amount of electricity generated would not be affected by the target rods.)

If DOE instead leased irradiation services at commercial reactors, the utilities would continue to own and operate the reactors and sell the electricity they generate.

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7. Light-water reactors use regular water to cool the reactor and moderate the nuclear reactions inside. They are distinguished from reactors that use "heavy water"—water that has an extra neutron in each of its hydrogen atoms.

The only difference would be that the utilities would include some of DOE's target rods in the fuel assemblies every time they refueled their reactors. DOE would pay the utilities for their services, which presumably would include compensation for the extra handling associated with the target rods. Whenever a utility refueled its reactor (about every one to two years), DOE would pick up the target rods and take them to the Savannah River extraction facility.

The Department of Energy plans to spend a total of nearly $600 million from 1996 through 2005 developing the ability to produce and extract tritium from light-water reactors (see Table 2). About $80 million of that will be authorized before the Secretary of Energy decides in late 1998 which tritium production method to use. During that time, DOE plans to build a test assembly of target rods and try it in a reactor, begin the process of securing approval from the Nuclear Regulatory Commission to use tritium-producing targets in commercial reactors, and make a conditional selection of reactors that could be purchased or used for irradiation services.

Regardless of which production method the Secretary chooses, DOE will follow the same course in its reactor program until 2003. Specifically, it will build the tritium extraction facility at Savannah River and fabricate the first reactor load of tritium-producing target rods. At that point, if the accelerator approach has been selected, activities for the reactor program will stop. DOE will have a proven and licensed backup source of tritium should the accelerator fail.

On the other hand, if the reactor approach has been chosen, DOE will activate its contract with one or more utilities in 2003 to purchase irradiation services or buy a reactor. The first load of target rods could be placed in a reactor in 2003, then removed in 2005 and sent to the extraction facility.

If irradiation services are selected, operations will cost about $50 million a year, according to DOE. Purchasing irradiation services would have some advantages for the department. It would obviate the responsibility of operating a utility, having to store spent fuel rods, and decontaminating and decommissioning the reactor at the end of its service life. But some members of the nonproliferation community believe using civilian reactors for military purposes would establish a troubling precedent. Indeed, keeping military and civilian reactors separate is something that the United States has advocated to other countries in its efforts to control the spread of nuclear weapons.

Purchasing an existing commercial reactor would avoid those proliferation concerns—one of the primary reasons that DOE is considering it. If the Secretary of Energy decides to take that approach rather than lease irradiation services, the

TABLE 2. COSTS OF DOE'S ALTERNATIVES TO PRODUCE TRITIUM (In millions of dollars)

Activities	Costs, 1997-2010
Reactor Selected as Primary Tritium Source	
Investment	
Develop target rods for reactor, build tritium extraction facility, select utilities, address regulatory issues	600[a]
Develop technology for accelerator, complete detailed engineering design	1,400
Build accelerator	n.a.
Subtotal	2,000[a]
Operations	
Purchase irradiation services and operate tritium extraction facility ($50 million a year)	350
Operate accelerator	n.a.
Total	2,350[a]
Accelerator Selected as Primary Tritium Source	
Investment	
Develop target rods for reactor, build tritium extraction facility, select utilities, address regulatory issues	600
Develop technology for accelerator, complete detailed engineering design	1,400
Build accelerator	4,000
Subtotal	6,000
Operations	
Purchase irradiation services and operate tritium extraction facility	n.a.
Operate accelerator ($180 million a year)	720
Total	6,720

SOURCE: Congressional Budget Office based on data from the Department of Energy.

NOTE: DOE = Department of Energy; n.a. = not applicable.

a. If DOE decides to purchase a commercial reactor rather than irradiation services, the totals shown here will be higher. The department estimates that it will have to spend an additional $1.9 billion in 2003 to buy the reactor, although revenue from selling the electricity produced by the reactor will offset some of those costs in later years.

department estimates that it will have to pay about $1.9 billion to buy a reactor from a utility, although revenue from selling the electricity produced by the reactor will offset some of those costs.

Tritium Accelerator. DOE's proposed tritium production accelerator, dubbed APT (for Accelerator Production of Tritium), will focus a beam of protons onto a tungsten target. When the protons strike the nuclei of the tungsten atoms, they free neutrons and protons. Those protons then strike other tungsten nuclei, which release more neutrons. Some of the neutrons from those collisions combine with helium gas surrounding the target and thus produce tritium. The tritium is separated continuously from the helium in a nearby extraction facility.

The Department of Energy has decided that the APT, if selected, would be built at the Savannah River Site. The entire accelerator would be about 1.5 kilometers long and would be located in concrete tunnels buried 30 to 50 feet underground to shield the environment from radiation emitted by the accelerator. The APT would consume large amounts of electrical power, which would be supplied by a commercial power plant operating nearby.

The accelerator in the APT would be about the same scale as the one at the Los Alamos Neutron Scattering Center, but it would use different technology in order to produce a more intense neutron beam and to operate continuously (compared with only about 6 percent of the time at the Los Alamos accelerator). The Department of Energy's APT program office claims that scientists have demonstrated the success of all of the accelerator's components independently, but have not yet proven that the components can function together or in the continuous operations expected for the APT.

If DOE selects the accelerator as its main tritium source, operations could begin in 2007—two years later than required by the 1996 Nuclear Weapons Stockpile Memorandum to support a START I stockpile and a five-year reserve. Assuming Russia does not ratify the START II treaty and those requirements do not change, DOE has four options to address the shortfall in production. It could use its backup approach and produce tritium in a commercial reactor for two years until the accelerator was ready, produce the gas in the Fast Flux Test Facility, draw down its five-year reserve for two years, or purchase the necessary tritium from another country, most likely Russia.

The APT program office expects to resolve some of the technical issues before late 1998, when the Secretary of Energy must decide which technology to use. It plans to test the "front end" of the accelerator to demonstrate that the components can function well together, evaluate their reliability and performance, and demonstrate the system's ability to operate at a 100 percent duty cycle. The program office also plans to demonstrate the ability of the targets to produce tritium and withstand the high radiation expected inside the accelerator.

According to the most recent data provided to the Congressional Budget Office, DOE estimates that the APT would cost $4.9 billion through 2007 to build and $180 million a year thereafter to operate. However, a 1995 analysis by the department indicated that there could be a wide range in construction costs. CBO estimates that the actual cost to build the accelerator would probably be $5.4 billion, and it uses that estimate throughout this paper.

If DOE selects a light-water reactor as the primary tritium source in 1998, work will continue on the APT through 2002 to establish the accelerator as a backup source by completing its technology demonstrations and engineering design. At that point, the accelerator could be built in five or six years, if necessary. Costs for the APT backup program would total $1.4 billion, according to DOE, or $4 billion less than completing the facility.

DOE's Long-Term Budget for Tritium. For planning purposes, DOE's long-term budget for 1997 through 2010 assumes that the department will build the APT by 2007 and rely on commercial reactors only as a backup. That would require the department to spend a total of $6 billion to build a tritium source and a backup—$5.4 billion to construct the APT and $600 million to establish a commercial light-water reactor as a backup within two years (see Table 2). In addition, DOE would spend about $720 million to operate the APT from 2007 through 2010. If instead DOE chose to build a reactor or lease irradiation services as its primary method, costs through 2010 would be one-third or two-thirds lower, respectively.

Pit Production Facility

The Department of Energy does not yet have enough experience with plutonium pits to know how they will hold up in the stockpile once they pass their designed service life. As a result, the weapons laboratories do not know how long pits will last before they must be replaced. In 1989, DOE closed its only pit production facility (at Rocky Flats, Colorado) for environmental and safety reasons, so any future production will have to be done at the small TA-55 research facility at Los Alamos. DOE anticipates that at most it will have to remanufacture or modify 50 pits each year to support a START II stockpile. That capability will be sufficient, in DOE's view, to replace the 20 or so pits that are lost each year to destructive testing and to build other pits as required. If, at some point in the future, DOE identifies a problem that could limit the life of the pits, it might need to expand the facility.

Reconfiguring TA-55 from a facility that produces a few pits each year for research to one better suited to producing up to 50 pits each year would cost roughly $500 million to $600 million, according to DOE. As part of its effort to move pit production to Los Alamos, DOE is also upgrading the Chemistry and Metallurgical Research Facility and the Nuclear Materials Storage Facility there, at a cost of more than $200 million.

CHAPTER IV

ALTERNATIVES TO DOE'S STOCKPILE STEWARDSHIP AND MANAGEMENT PROGRAM

Several alternatives to the Stockpile Stewardship and Management Program exist that the Congress may want to consider. In this paper, the Congressional Budget Office examines the effects of four of them (see Table 3). The first alternative illustrates how retaining a START I-size nuclear stockpile instead of making planned reductions could alter the Department of Energy's budget. The second shows the effect that much larger cuts in the stockpile would have on the costs of the stewardship and management program, assuming that no changes were made to DOE's basic approach.

The third and fourth alternatives illustrate the impact of reducing the stewardship and management program. Alternative 3 attempts to keep much of DOE's philosophy intact, but at lower cost, by reducing the size of one weapons laboratory. It would also keep costs down by using a commercial reactor to produce tritium instead of developing an accelerator. Alternative 4 shows the effects of a "minimal" stewardship philosophy that places more emphasis on understanding how primaries work and replacing aging components, and less emphasis on learning as much as possible about the physics of secondaries. Of course, features of the alternatives could be combined; the costs or savings from each option are detailed below to allow readers to make trade-offs.

The estimates of savings measure the effect of each alternative on the Stockpile Stewardship and Management Program—the Administration's plan for living under START II and the Comprehensive Test Ban Treaty. The estimates are not intended to project the costs or savings of either treaty. Estimating such costs requires considering many factors that are outside the scope of this analysis. Instead, the effects of the alternatives are expressed relative to CBO's estimate of the Administration's plan for the stewardship and management program.

The Administration's plan for the Department of Energy was presented in DOE's recent budget for 1998 through 2002 and its long-term spending projections (through 2010) released last year. To be consistent with the long-term estimates, CBO made one change to the Administration's plan for 1998 through 2002. It added back the funds required to build an accelerator for producing tritium, which DOE had included in the long-term plan but omitted from the 1998 budget.

TABLE 3. EFFECTS OF ILLUSTRATIVE ALTERNATIVES ON DOE'S STOCKPILE STEWARDSHIP AND MANAGEMENT PROGRAM

Alternative	Effect on Stewardship	Effect on Readiness at NTS	Effect on Production Complex	Savings from the Administration's Plan Through 2010 (In billions of dollars)
1. START I Levels Retained	None	None	Double production rates	-1.5[a]
2. Deep Cuts (START III)	None	None	Reduce production by two-thirds, delay tritium production	6.5[b,c]
3. START II for Less	Partially consolidate labs, build NIF and other new facilities	Close NTS	Cancel tritium accelerator	8.4[c]
4. Minimal Stewardship	Partially consolidate labs, cancel NIF and other new facilities	Close NTS	Double production of nuclear components	3.3

SOURCE: Congressional Budget Office.

NOTE: NTS = Nevada Test Site; START = Strategic Arms Reduction Treaty; NIF = National Ignition Facility.

a. Because the Administration's plan assumes that START II will be ratified and U.S. forces will be reduced from current levels, Alternative 1 would raise costs for the stewardship and management program. This estimate reflects only Department of Energy costs. Keeping U.S. forces at START I levels would also increase costs for the Department of Defense by $11 billion through 2010, assuming that the United States kept all 50 MX missiles, kept 18 Trident submarines capable of carrying D5 missiles, and did not buy any more bombers.

b. This estimate reflects only Department of Energy savings. It excludes the $16 billion that the Department of Defense might save through 2010 by reducing its forces under a START III treaty, assuming that it retained the so-called nuclear triad by deploying 200 Minuteman missiles, 10 Trident submarines, and 40 B-52 bombers.

c. The savings from Alternatives 2 and 3 assume that the Department of Energy would build an accelerator to produce tritium. Money for its construction was included in the Department of Energy's long-term plan last year but was omitted from its 1998 budget plan. CBO restored the funds in estimating the cost of the Administration's plan.

ALTERNATIVES THAT WOULD CHANGE THE SIZE OF THE STOCKPILE

The future size of the U.S. nuclear stockpile is unclear. Russia has not yet ratified the START II treaty. If it does not, the United States may retain a larger stockpile than the treaty calls for. Meanwhile, several prominent analysts and former military officials in the United States and Russia are urging deep reductions in nuclear forces. The first two alternatives would alter the size of the planned stockpile, either by forgoing any further reductions or by making substantial cuts.

Alternative 1: Keep the Stockpile at Today's Level (START I)

The fate of the second Strategic Arms Reduction Treaty is up in the air; the United States has ratified it but Russia has not. Some members of the Russian parliament have expressed concern about the cost of carrying out the treaty, which will require Russia to build hundreds of new, single-warhead missiles to replace those with multiple warheads that it must destroy. Others are worried about the asymmetries in U.S. and Russian forces that would allow the United States to increase its forces much more rapidly. Still others worry about the planned expansion of NATO into Eastern Europe and U.S. plans to build a national missile defense. Observers are divided about whether Russia will ratify the treaty or will add amendments that the United States finds unacceptable.

What would happen in the absence of ratification? One possibility is that Russia would abide by the terms of the treaty anyway, much as the United States kept within the limits of the second Strategic Arms Limitation Treaty (SALT II) during the 1980s even though the Senate never voted to ratify it. Many analysts believe that is the most likely outcome, because Russia's budgetary constraints will make fielding larger forces very difficult. But another possibility is that Russia will keep its forces at START I levels, much as they are today. Exactly how the United States would respond to that is unknown, but it could decide to do the same thing.

This alternative illustrates the costs to DOE if the United States and Russia were to keep their forces at START I levels for the foreseeable future. However, it should not be considered an estimate of the costs of complying with the START II treaty, which is outside of the scope of this paper.

Because the stewardship activities at the weapons laboratories are largely independent of the size of the stockpile, this alternative would have no effect on their budgets. A larger stockpile would, however, have a small but measurable effect on stockpile management—more weapons and more types would have to be supported with spare parts, nuclear components, and tritium.

Effect on Production. Alternative 1 would significantly affect the number of components that DOE must produce each year because it would retain roughly twice the number of warheads after 2003 that would be kept in the stockpile under the Administration's plan for START II. According to DOE, maintaining a START I stockpile could require the department to fabricate twice as many nonnuclear components, pits, secondaries, and radiation cases and modify twice as many pits for reuse (see Table 4). It would also double the number of weapons that would need to be rebuilt each year as part of DOE's program to refurbish or replace warheads in the stockpile. But keeping a START I stockpile would increase by only one-sixth the number of warheads that DOE would have to evaluate each year because the rate is determined largely by how many types of warheads are in the stockpile rather than the number of warheads. DOE estimates that under START I, it would have to produce twice as many sets of high explosives to support its warhead rebuilding and surveillance programs.

For most components, sufficient quantities could be manufactured without new investments because DOE is sizing almost all of its production facilities to support a START I stockpile (see Table 4). Output would simply be increased by hiring more workers. For pit production, however, additional investments would have to be made to increase capacity.

This alternative would have no effect on tritium production because the Administration's plan already assumes that DOE will be able to produce tritium in time to support a START I stockpile. That policy is dictated by the 1996 Nuclear Weapons Stockpile Memorandum, which assumes that the active stockpile will remain at START I levels at least until Russia ratifies START II. That assumption represents a change from the previous year's Nuclear Weapons Stockpile Memorandum, which assumed that the number of warheads would be cut to START II levels by 2003. To accommodate the new policy, the Administration has accelerated its schedule for producing new tritium by six years, from 2011 to 2005.

Effect on Costs. Despite doubling the production of most components after 2003 compared with START II levels, the additional costs of maintaining a START I stockpile indefinitely would be quite small for DOE. The department's costs would be an average of $190 million higher each year from 2003 to 2010 than under the Administration's plan (see Figure 10 on page 58). No increases would be required before 2003 because the Administration plans to maintain the stockpile at START I levels until START II has been fully implemented. Through 2010, Alternative 1 would increase costs for DOE by a total of $1.5 billion, or less than 3 percent (see Table 5 on page 59).

Those costs exclude the additional funds that the Department of Defense would have to spend to keep its forces at START I levels. CBO estimates that its extra costs would total $11 billion through 2010 (see Box 2 on page 60).

TABLE 4. ANNUAL PRODUCTION RATES FOR DIFFERENT STOCKPILE SIZES

	DOE's Planned Capacity	Alternative 1 (START I)	Administration's Plan (START II)	Alternative 2 (START III)
Number of Weapons Assembled and Disassembled Each Year				
Rebuild Weapons				
Disassemblies	300	300	150	50
Assemblies	300	300	150	50
Evaluate Weapons				
Disassemblies	140	140	120	120
Assemblies	140	140	110	110
Number of Components Produced Each Year				
High Explosives	300	300	150	50
Nonnuclear Components	600	up to 600	up to 300	up to 100
Nuclear Components				
Pit fabrication	50	100	50[a]	50[a]
Pit reuse	150	200	100	50
Secondaries and radiation cases	300	100	50[a]	50[a]

SOURCE: Congressional Budget Office based on Department of Energy, *Final Programmatic Environmental Impact Statement for Stockpile Stewardship and Management*, vol. 1 (September 1996), p. 3-4, *Stockpile Management Preferred Alternatives Report* (July 1996), and *Analysis of Stockpile Management Alternatives* (July 1996).

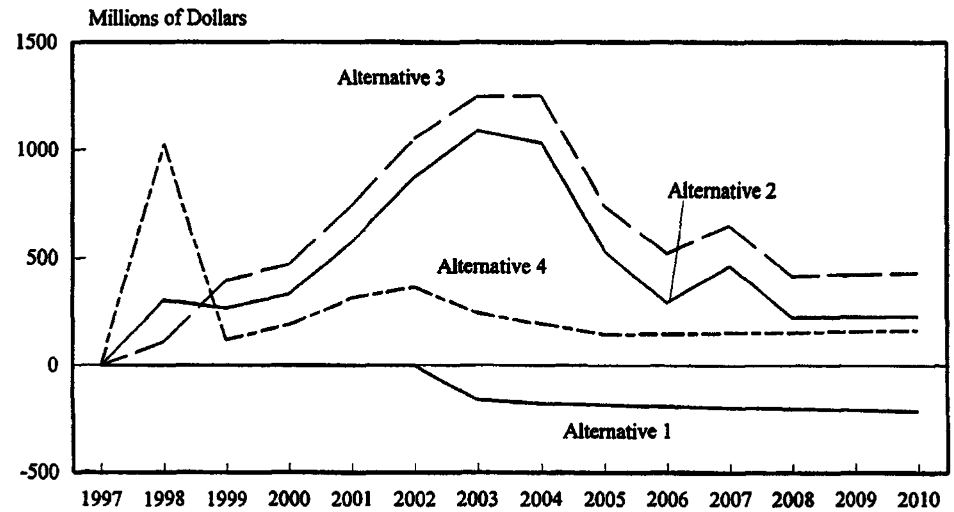
NOTES: DOE = Department of Energy; START = Strategic Arms Reduction Treaty.

The Department of Energy's estimated production rates assume a single operating shift. In most cases, it could increase output by adding shifts.

a. The Department of Energy requires that its production facilities retain the infrastructure, equipment, and skills to fabricate pits and secondaries for every type of weapon expected to remain in the stockpile. According to the department, this creates an inherent capacity to build up to 50 pits and secondaries each year. The actual production rate for START II and START III would be smaller, perhaps about 20 components each year.

Doubling production rates would not produce bigger increases in DOE's costs because much of the stewardship and management budget is independent of the size of the stockpile. As noted above, the stewardship budget would not change under Alternative 1. Furthermore, most of the stockpile management budget would not be affected, for two reasons. First, DOE will carry out most of its stockpile management activities regardless of the size of the arsenal. Of the $1.9 billion the department plans to spend on stockpile management in 1997, only about 9 percent will be devoted to producing new components and rebuilding and maintaining weapons. The rest will fund dismantling weapons, enhancing surveillance technologies, supporting production, maintaining infrastructure, developing a source of tritium, developing advanced production technologies, and other, miscellaneous efforts (see Figure 11 on page 61). Second, DOE already plans to size most of its production facilities so they can easily support a START I stockpile if necessary. Thus, the only real cost it will face from actually keeping a START I stockpile is the relatively small amount to increase production above planned levels.

FIGURE 10. ANNUAL SAVINGS FROM CBO'S ALTERNATIVES THROUGH 2010



SOURCE: Congressional Budget Office

NOTE: Estimates of savings are for the Department of Energy only. Costs for Alternative 1 exclude the money that the Department of Defense would have to spend (about $11 billion through 2010) to keep its forces at START I levels. Savings for Alternative 2 exclude the savings that DoD could achieve by reducing its forces to START III levels ($16 billion through 2010). The savings for Alternatives 2 and 3 assume that the Department of Energy would opt to build a tritium accelerator. Money for its construction was included in the department's long-term plan last year but was omitted from its 1998 budget plan.

If Russia's unwillingness to ratify START II signaled a renewed nuclear competition, however, the Department of Energy might reevaluate its plans for consolidating the production complex and decide to build more capacity into its facilities. That would increase the costs of this option. Indeed, a sharp change in Russia's nuclear policies would unravel much of the basis for the United States' planning for its nuclear forces and would have profound effects on budgets for DOE and the Defense Department.

TABLE 5. SAVINGS FROM CBO'S ALTERNATIVES (In millions of dollars)

	1997	1998	1999	2000	2001	2002	Total, 1997-2002	Total, 1997-2010
Cost of the Administration's Plan[a]								
DOE's Stewardship and Management Program	3,910	5,080	4,170	3,950	4,260	4,320	25,690	61,160
Savings from CBO's Alternatives								
1. START I Levels Retained	0	0	0	0	0	0	0	-1,520[b]
2. Deep Cuts (START III)	0	300	270	330	570	870	2,350	6,450[c,d]
3. START II for Less	0	110	400	470	740	1,050	2,760	8,440[d]
4. Minimal Stewardship	0	1,020	120	180	310	360	1,990	3,330

SOURCE: Congressional Budget Office based on data from the Department of Energy.

NOTE: DOE = Department of Energy; START = Strategic Arms Reduction Treaty.

a. CBO includes the cost of building an accelerator to produce tritium in its estimate of the cost of the Administration's plan. That cost was included in the Department of Energy's long-term plan last year but was omitted from its 1998 budget plan.

b. Because the Administration's plan assumes that START II will be ratified and U.S. forces will be reduced from current levels, Alternative 1 would raise costs for the stewardship and management program. This estimate reflects only DOE costs. Keeping U.S. forces at START I levels would also increase costs for the Department of Defense by $11 billion through 2010, assuming that the United States kept all 50 MX missiles, kept 18 Trident submarines capable of carrying D5 missiles, and did not buy any more bombers.

c. This estimate reflects only Department of Energy savings. It excludes the $16 billion that the Department of Defense might save through 2010 by reducing its forces under a START III treaty, assuming that it retained the so-called nuclear triad by deploying 200 Minuteman missiles, 10 Trident submarines, and 40 B-52 bombers.

d. The savings from Alternatives 2 and 3 assume that the Department of Energy would build an accelerator to produce tritium. Savings would be smaller compared with a baseline in which the department used a commercial reactor instead.

Alternative 2: Reduce the Stockpile to 1,000 Strategic Warheads (START III)

This alternative illustrates the effect of cutting the U.S. stockpile sharply under a third START treaty, without making any other changes to DOE's Stockpile Stewardship and Management Program. Several analysts have proposed that the United States and Russia reduce their arsenals below the START II level of 3,000 to 3,500 strategic warheads. (Strategic warheads are those carried by missiles and bombers with intercontinental ranges.) The idea of cutting back to 2,000 warheads has gained some popularity in Russia because it would save money; the country could reduce

BOX 2.

POSSIBLE EFFECTS OF THE ALTERNATIVES ON DoD FORCES

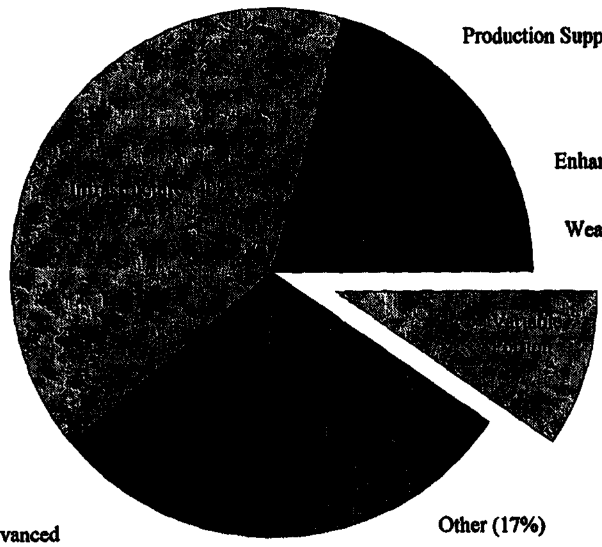
Alternatives 1 and 2 examine the effects that changes in the size of the stockpile would have on the Department of Energy. But returning to START I levels or making sharp reductions below START II levels would also affect the nuclear forces deployed by the Department of Defense (DoD).

Today, the United States deploys 50 MX and 500 Minuteman III intercontinental ballistic missiles, 18 Trident submarines loaded with 24 missiles each, and 160 long-range bombers. Under START II, the Administration plans to eliminate all 50 MX missiles, retire four Trident submarines, and convert all 90 B-1B bombers to conventional roles. In addition, it will modify (backfit) the four oldest Trident submarines that will remain in the fleet to carry the larger D5 missile that the other Tridents already carry. To stay within the warhead limits specified in START II, the United States will also reduce the number of warheads on its Minuteman missiles from three to one and on D5 missiles from eight to five.

If Russia fails to ratify the START II treaty, the United States may well keep its forces at today's level and increase the number of warheads to START I levels. That is the scenario postulated in Alternative 1. In that case, the Congressional Budget Office (CBO) assumed that the United States would keep its MX missiles and all 18 Trident submarines and would retain a nuclear capability for all of its heavy bombers. It would also put D5 missiles on the four submarines it would otherwise have retired and buy an additional 100 or so missiles to fill the submarines. Those changes would cost DoD about $11 billion through 2010.

Alternatively, if the number of deployed warheads were cut to 1,000 under an illustrative START III treaty, U.S. forces would be smaller. Since such a treaty does not exist, it is not clear what those forces would look like. But to provide a conservative illustration of the reduction in forces that might be required, CBO assumed that the United States would retain its triad of land-based missiles, sea-based missiles, and bombers. Accordingly, those forces would include 200 Minuteman missiles, each with one warhead; 10 Trident submarines, each with 24 missiles loaded with two warheads; and 40 B-52 bombers, each loaded with eight cruise missiles. (CBO assumed that the rest of the bomber force would not be affected by a START III treaty and would continue to perform conventional missions.) The savings to DoD would total $16 billion through 2010.

FIGURE 11. BREAKDOWN OF 1997 COSTS FOR STOCKPILE MANAGEMENT



SOURCE: Congressional Budget Office based on data from the Department of Energy.

NOTE: The total budget for stockpile management in 1997 is $1.9 billion.

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the number of new, single-warhead intercontinental ballistic missiles that it would need to deploy under START II to keep warheads at levels allowed by the treaty. At the recent summit meeting in Helsinki, President Clinton made such a proposal in order to encourage Russia's parliament to ratify the START II treaty. He offered to begin negotiating a third START treaty—after the second is ratified—that would reduce the number of warheads to between 2,000 and 2,500 on each side.

In both the United States and Russia, a number of prominent writers have proposed reductions to levels of 1,000 warheads or fewer.[1] They have been motivated by concern that Russia may not ratify START II but might ratify a treaty calling for smaller numbers of nuclear weapons (and thus entailing lower costs), and also by concern that the large stockpiles of nuclear weapons and fissile materials in Russia pose a danger of proliferation.

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1. See General Lee Butler, USAF (Ret.), "Time to End the Age of Nukes," *Bulletin of the Atomic Scientists* (March-April 1997), pp. 33-36; and Michael E. Brown, *Phased Nuclear Disarmament and U.S. Defense Policy*, Occasional Paper No. 30 (Washington, D.C.: Henry L. Stimson Center, October 1996).

This alternative assumes that a third START treaty would limit the active stockpile to 1,000 warheads, including both strategic and tactical nuclear weapons (shorter-range weapons that are deployed on naval cruise missiles and tactical aircraft). Treaty negotiations are assumed to conclude by the end of 1997. Reductions would start in 2003 and would be finished by the end of 2005, two years after the reductions mandated by START II are supposed to be complete.

With a total of about 1,000 deployed strategic warheads (and perhaps several hundred warheads deployed with short-range forces), this START III stockpile would be roughly one-third the size of the START II force. An active stockpile of 1,000 strategic weapons may be smaller than some supporters of a START III treaty would advocate, but it serves to illustrate that deep cuts in the stockpile will produce modest savings in DOE's budget as long as the United States does not alter the way that it plans to do business. Of course, deep cuts in nuclear forces would produce significant savings in the Defense Department's budget—not included here—for the bombers, missiles, and submarines that carry nuclear warheads.

Effect on Production. Under Alternative 2, the number of nonnuclear components DOE would have to produce and the number of weapons it would have to rebuild would fall by two-thirds (see Table 4 on page 57). Production rates for nuclear components would decline more modestly, largely because the number of components that are expected to be consumed in tests would remain unchanged from the START II level. With such deep cuts in warheads, DOE could delay producing tritium for years and could reduce the capacity of the production facility by about two-thirds from the level now planned. However, stockpile stewardship efforts would not change.

Effect on Costs. Taken together, the changes under Alternative 2 could produce substantial savings compared with CBO's estimate of the cost of the Administration's plan. Assuming that the smaller arsenal was phased in over three years starting in 2003, and that the current stockpile stewardship program remained the same, the Department of Energy would save $300 million in 1998, $2.4 billion through 2002, and $6.5 billion through 2010 (see Table 6). The lion's share of those savings, $5.8 billion, would come from delaying tritium production until well after 2010. The remaining $640 million would come from reducing most other production activities by two-thirds.

Those estimates exclude the money that the Department of Defense would save by reducing its nuclear forces. CBO estimates that reducing the stockpile to 1,000 warheads would lower DoD's costs by $16 billion through 2010, assuming that the United States retained its triad of land-based missiles, submarine-based missiles, and bombers (see Box 2 on page 60).

Savings from reducing component production would be modest considering that the number of warheads would drop by two-thirds. The reasons are the same as in Alternative 1: a significant fraction of core stockpile management activities are fixed, so more than 90 percent of the budget is not affected by the size of the stockpile. Moreover, production rates for pits, secondaries, and modified pits are determined by the need to retain workers' skills and replace components lost in destructive testing rather than by the size of the stockpile, DOE says. Furthermore, the number of warheads that DOE would disassemble and rebuild each year as part of its stockpile evaluation program is driven by the need to inspect a sample of weapons large enough to predict reliability and would be largely unchanged from the number planned under START II. As a result, supporting a stockpile of 1,000 warheads (excluding tritium production) would save only about $90 million a year after 2005.

Of course, the major effect of deep cuts would be to lower the demand for tritium. CBO estimates that DOE would need only about one-third of the tritium to

TABLE 6. SAVINGS FROM ALTERNATIVE 2: DEEP CUTS (In millions of dollars)

	1997	1998	1999	2000	2001	2002	Total, 1997-2002	Total, 1997-2010
Stockpile Stewardship	0	0	0	0	0	0	0	0
Stockpile Management								
Reduce component production	0	0	0	0	0	0	0	640
Delay tritium production[a]	0	300	270	330	570	870	2,350	5,810
Total	0	300	270	330	570	870	2,350	6,450

SOURCE: Congressional Budget Office based on data from the Department of Energy.

NOTE: These estimates reflect only Department of Energy savings. They exclude the $16 billion that the Department of Defense might save through 2010 by reducing its forces under a START III treaty, assuming that it retained the so-called nuclear triad by deploying 200 Minuteman missiles, 10 Trident submarines, and 40 B-52 bombers.

a. The savings from Alternative 2 assume that the Department of Energy would build an accelerator to produce tritium. Money for its construction was included in the department's long-term plan last year but was omitted from its 1998 budget plan. CBO restored the funds in its estimate of the costs of the Administration's plan. Savings would be smaller compared with a baseline in which the department used a commercial reactor instead.

support an active stockpile of 1,000 warheads (including a five-year reserve) that it would need for a START II stockpile. Thus, any tritium production accelerator DOE constructed could be smaller and could cost less to build and operate.

Moreover, under Alternative 2, DOE would delay building and operating its tritium source for 20 years because it could recycle gas from the weapons dismantled under the START III treaty. The money saved now would have to be spent in later years to build a production facility, but delaying that spending would significantly reduce what economists call the opportunity cost—the cost of investing in a project today versus investing in the future. The savings would be offset partially, however, because CBO assumed that DOE would continue to develop the technologies for both accelerator- and reactor-based approaches to tritium production, although at a slower pace than now planned (spending an average of $50 million a year through 2010, for a total of $650 million).

To achieve greater savings from deep cuts in the stockpile, DOE would have to make changes in its approach to stewardship and management like those in Alternatives 3 and 4. CBO selected a 1,000-warhead stockpile for this alternative to illustrate the savings from such deep cuts. Savings would be lower if arsenals were reduced more modestly, such as Presidents Clinton and Yeltsin suggested at the Helsinki summit meeting. Also, savings could be lower if a START III treaty required the United States to verify the dismantling of warheads.

ALTERNATIVES THAT WOULD REDUCE FUNDING FOR STEWARDSHIP

Critics of DOE's approach to stockpile stewardship and management have proposed other approaches that would reduce the scale of the program. Some would preserve the same basic philosophy for stewardship but at lower cost. Others would adopt a different philosophy: focusing less on laboratory experiments, particularly those directed at the secondary, and relying more on replacing aging components.

The central question underlying any approach is, What is required to ensure the reliability and safety of the stockpile in the future if the moratorium on underground nuclear testing becomes permanent? DOE's stewardship and management program is the Administration's answer. Alternatives 3 and 4 present two other answers.[2]

2. For a discussion of several other approaches, see Jonathan Medalia, *Nuclear Weapons Stockpile Stewardship: Alternatives for Congress*, CRS Report for Congress 96-11 F (Congressional Research Service, December 14, 1995).

Alternative 3: Trim Stewardship and Produce Tritium in a Reactor (START II for Less)

One approach would be to do much of what DOE wants for stewardship but for less money. Proponents make several arguments for scaling back the stewardship program. Reducing costs is one. Another is the concern that DOE's science-based stewardship would give the appearance that the United States will continue to develop and produce new types of nuclear weapons under the Comprehensive Test Ban Treaty.

Accordingly, this alternative would trim the size of the stewardship program by consolidating much of the work at one design laboratory and forgoing all readiness activities and hydrodynamic testing at the Nevada Test Site (see Table 3 on page 54). It would also reduce the cost of managing the stockpile by canceling the development and construction of an accelerator for tritium production and relying instead on purchasing irradiation services from commercial reactors.

For illustrative purposes, Alternative 3 assumes that most nuclear research and design activities would be consolidated at Los Alamos over a period of five years. Lawrence Livermore would no longer have nuclear weapons work as its primary focus, although it would remain open, and weapons work would continue there at about one-third of today's level. Sandia would remain in its present form as DOE's engineering lab, but its California facility, which supports Lawrence Livermore, would probably be smaller.

Los Alamos designed five of the seven types of warheads that are likely to remain in the active stockpile. To ensure that the other types could be reliably maintained, some designers from Livermore would probably have to move to Los Alamos. This alternative would also maintain a cadre of weapons scientists at Livermore to provide peer review for Los Alamos's efforts. To make sure they had challenging work and to attract new scientists to the weapons program, Lawrence Livermore would keep substantial computational facilities for modeling the complex processes inside nuclear weapons and would proceed with plans to build the National Ignition Facility. However, the Contained Firing Facility at Livermore would be canceled, and all hydrodynamic work would be centered at Los Alamos. (Savings would be lower if stewardship activities were consolidated at Lawrence Livermore because that would involve moving more facilities and relocating more weapons designers. Also, the environmental issues raised by introducing new nuclear facilities into the populous area surrounding Livermore could prove difficult to overcome.) Together, all of those changes would reduce employment by about 2,000 people, or 25 percent of those involved in stockpile stewardship at the three weapons labs today.

Effect on Costs. Taken together, the changes in Alternative 3 would save DOE $110 million in 1998 and $2.8 billion through 2002 compared with the CBO's estimate of the Administration's plan (see Table 7). Through 2010, DOE could save $8.4 billion. The savings would come primarily from three sources. Partially consolidating the labs would begin in 1998 and take five years; savings would reach about $190 million a year after that, for a total of $2.1 billion through 2010. Halting all testing and readiness activities at the Nevada Test Site (NTS) by 1998 would save about $70 million annually and a total of about $910 million through 2010. Canceling the

TABLE 7. SAVINGS FROM ALTERNATIVE 3: START II FOR LESS
(In millions of dollars)

	1997	1998	1999	2000	2001	2002	Total, 1997-2002	Total, 1997-2010
Stockpile Stewardship								
Consolidate labs	0	20	60	90	130	170	470	2,090
Cancel Contained Firing Facility	0	30	a	0	0	0	30	30
End NTS readiness	0	60	70	70	70	70	320	910
Subtotal	0	110	120	160	200	230	810	3,030
Stockpile Management (Cancel tritium accelerator and use commercial reactor)	0	0	270	310	550	820	1,950	5,420
Total	0	110	400	470	740	1,050	2,760	8,440

SOURCE: Congressional Budget Office based on data from the Department of Energy.

NOTES: START = Strategic Arms Reduction Treaty; NTS = Nevada Test Site.

The savings from Alternative 3 assume that the Department of Energy would build an accelerator to produce tritium. Money for its construction was included in the department's long-term plan last year but was omitted from its 1998 budget plan. CBO restored the funds in its estimate of the costs of the Administration's plan. Savings would be smaller compared with a baseline in which the department used a commercial reactor instead.

a. Less than $5 million.

tritium production accelerator and instead purchasing irradiation services from commercial reactors would save $1.9 billion through 2002 and $5.4 billion through 2010.

Pros and Cons of Trimming Stewardship. Supporters of DOE's stewardship program may argue that Alternative 3 would cut the program too deeply. They believe that the Administration's plan is the minimum effort necessary to maintain the stockpile without underground testing. In their view, two design laboratories are essential for providing a robust stewardship program; competition and peer review will be even more important in the absence of underground testing. Furthermore, they argue, refocusing the efforts of one lab away from weapons research would eliminate its central unifying mission (and thus its motivation for excellence) without replacing that focus with an equally important mission. Some supporters of retaining both laboratories say that experienced weapons scientists would leave the labs if the stewardship program was cut so much that they no longer had confidence in their ability to certify the reliability and safety of the stockpile to the President. Moreover, consolidation would result in the loss of some facilities that could not easily be transferred to the other lab. For many of those reasons, the President recently directed DOE to retain both laboratories.

Advocates of DOE's stewardship program would also take issue with this alternative's plan to close NTS contrary to Presidential directive. Doing so would increase the time required to resume underground testing from three to perhaps five years if Russia started a new arms race or the United States discovered a serious problem with its stockpile that could only be corrected through underground nuclear testing. Perhaps more important to some critics, closing the test site would mean that the labs would lose some of the unique facilities there. For example, without the Lyner Facility the labs would have trouble conducting subcritical experiments with plutonium—experiments that will help weapons scientists understand how this unique material changes over time and how those changes might affect the performance of the primary. Losing the Big Explosives Experimental Facility at NTS might also limit their ability to conduct pulsed-power experiments using high explosives. Both types of experiments could possibly be conducted at Los Alamos, but they would have to be smaller, and the cost of containment would be high.

Supporters of this alternative contend that it would preserve the most important elements of DOE's stewardship plan but would do so more efficiently. It would build the Dual-Axis Radiographic Hydrodynamic Test Facility and the National Ignition Facility. It would provide peer review, although not at the same level as DOE's plan. It would also opt for an inexpensive but proven source of tritium.

Perhaps more attractive to advocates than its lower cost, Alternative 3 is more consistent with deemphasizing the role of nuclear weapons—the true intent of the CTBT, in their view. By consolidating laboratories, this alternative would scale back the research and design program. By halting the NTS readiness program, it would eliminate the impression that the United States is poised to restart underground testing quickly. If the nation ever really needed to resume nuclear testing, it could do so within five years. And if there was a national crisis, proponents argue, testing could be resumed much more quickly.

Some critics even argue that the stewardship program should be cut further than Alternative 3 would do. They take issue with DOE's basic stewardship philosophy—which this option would retain, for the most part—and argue that the reliability of the stockpile can be maintained without building new experimental facilities. Alternative 4 examines some of those proposals.

Pros and Cons of Canceling the Tritium Production Accelerator. Canceling the production accelerator would delay for the foreseeable future the promise of "clean" production of tritium without having to use a nuclear reactor. Instead, this alternative would rely on an aging pool of civilian reactors. Perhaps most important to some people, relying on commercial reactors to produce tritium would blur the distinction between military and civilian reactors—behavior that the United States has actively discouraged. In the view of those critics, the $5.4 billion savings from canceling the accelerator is overshadowed by the potential arms control problems raised by using commercial reactors for military purposes. Nor would the savings justify relying on a production method that produces extremely hazardous wastes for which a permanent method of disposal does not yet exist. Furthermore, although DOE has explored the idea of buying irradiation services from commercial reactors, and the utilities that operate the reactors seem interested, forgoing the accelerator might be premature until DOE was certain that regulatory and political hurdles could be addressed and that commercial services would be available.

Readers who like the approach to stewardship in Alternative 3, but would prefer that the United States produce tritium in an accelerator, can use the subtotal for stockpile stewardship in Table 7 to calculate savings: about $3 billion through 2010. Alternatively, readers who want some of the savings possible from canceling the accelerator, but are concerned about using civilian reactors for military purposes, could adopt an approach in which DOE would purchase a civilian reactor. That would reduce the total savings from Alternative 3 by about $1.9 billion, DOE's estimate of the cost of buying a reactor.

Supporters of canceling the accelerator argue that producing tritium by purchasing irradiation services from the nation's utilities would save billions of dollars—savings that they believe more than outweigh any arms control concerns. Moreover, they reason that the norm against using commercial reactors for military purposes is intended to stop the production of fissile materials such as plutonium, not tritium. Tritium is already produced commercially and has commercial uses. And arguably, once a country reaches the point where it could use tritium to improve its weapons, the proliferation battle has already been lost. Furthermore, producing tritium in commercial reactors should have little, if any, effect on the amount of spent nuclear fuel that is produced. The only additional wastes would come from the used target rods. Finally, the Department of Energy could always choose to build an accelerator in the future if the aging inventory of commercial reactors became a problem.

Alternative 4: Consolidate the Labs and Cancel NIF and Other New Facilities (Minimal Stewardship)

Some critics of DOE's plans reject the underlying philosophy of the science-based Stockpile Stewardship and Management Program. They challenge the notion that weapons scientists must seek as much knowledge as possible about how weapons work.[3] Instead, they advocate a policy of "minimal" stewardship in which the reliability of the stockpile would be maintained by enough experiments to certify that the primaries will work. Secondary physics would receive lower priority.

Supporters of minimal stewardship point out that today's weapons have already been certified to work properly during both extensive underground nuclear tests before being deployed and some postdeployment "stockpile certification" tests. As a result, they reason, DOE could preserve reliability through its stockpile inspection program, replacing aging parts before performance was affected. In most cases, those replacement parts would be built to the original specifications. In some cases, however, building identical parts would be difficult or impossible because the materials or processes used to make the originals are no longer available or no longer acceptable for use under modern environmental, safety, and health standards. In other instances, DOE might choose instead to design new, more reliable replacements for components that have proven to be troublesome.

To reflect the views of supporters of minimal stewardship, this alternative would significantly reduce the size of the stewardship program by canceling most new test facilities as well as the partial consolidation of laboratories done in Alternative 3 (see Table 3 on page 54). The labs would use existing facilities: Nova

3. See, for example, Tom Zamora Collina and Ray E. Kidder, "Shopping Spree Softens Test-Ban Sorrows," *Bulletin of the Atomic Scientists* (July-August 1994), pp. 23-29; and Greg Mello, *No Serious Problems: Reliability Issues and Stockpile Management*, Tri-Valley CARES (Livermore, Calif.: Citizens Against a Radioactive Environment, February 6, 1995).

instead of NIF, Pegasus II instead of Atlas, and DARHT instead of the Contained Firing Facility and the Advanced Hydrodynamic Test Facility. Alternative 4 would continue the Accelerated Strategic Computing Initiative—although, without all of the new experimental facilities, weapons designers would not be able to validate the new three-dimensional models to the degree they would like. This alternative would also eliminate all testing and readiness activities at the Nevada Test Site, both to save money and to adhere to the spirit of the CTBT by underlining the U.S. commitment not to conduct tests.

Exactly how minimal stewardship would affect the weapons production complex is not clear. DOE might replace nuclear components at higher rates under this alternative because there would be more uncertainty about the effects of aging on them. The replacement rate it would choose is unknown, however. To illustrate an upper limit on what might be required, CBO assumed that production of pits and secondaries would increase to the levels DOE would use for a START I stockpile. That implies a replacement rate for primaries and secondaries that is twice what DOE plans under START II. For reasons explained in Alternative 1, increasing the replacement rate would increase costs only marginally—by no more than $110 million a year.

To avoid the proliferation issues raised in Alternative 3 by using a commercial reactor to produce tritium, Alternative 4 would continue with DOE's plan to build an accelerator. It would also increase funding for enhanced stockpile surveillance by 20 percent to improve further DOE's ability to detect age-related problems in the stockpile.

Effect on Costs. Total savings under Alternative 4 would be $1 billion in 1998 and $2 billion through 2002 (see Table 8). Through 2010, this alternative would save $3.3 billion. Savings would be only 40 percent of those achieved by Alternative 3 because this option would build the tritium accelerator. Apart from the accelerator, though, savings would be about the same as in Alternative 3: the amount saved over the next several years from canceling several large stewardship facilities under this alternative would be offset in later years by the costs of producing more nuclear components. Of course, if DOE did not reach the replacement rates assumed in Alternative 4 for pits and secondaries, savings could be higher by several hundred million dollars.

Readers who like Alternative 4's approach to stewardship, but believe that the lower costs of producing tritium in a commercial reactor outweigh the proliferation concerns, could add $5.4 billion in savings to this alternative by leasing irradiation services (see the savings from canceling the accelerator in Table 7).

TABLE 8. SAVINGS FROM ALTERNATIVE 4: MINIMAL STEWARDSHIP (In millions of dollars)

	1997	1998	1999	2000	2001	2002	Total, 1997-2002	Total, 1997-2010
Stockpile Stewardship								
Consolidate labs	0	20	60	90	130	170	470	2,090
End NTS readiness	0	60	70	70	70	70	320	910
Cancel NIF	0	910	10	10	0	0	930	930
Cancel CFF	0	30	a	0	0	0	30	30
Cancel Altas	0	20	0	0	0	0	20	20
Cancel AHT	0	0	0	30	130	140	290	440
Subtotal	0	1,030	130	200	320	370	2,050	4,420
Stockpile Management[b]								
Increase surveillance	0	-12	-12	-12	-12	-12	-60	-170
Increase component production	0	0	0	0	0	0	0	-910
Subtotal	0	-12	-12	-12	-12	-12	-60	-1,080
Total	0	1,020	120	180	310	360	1,990	3,330

SOURCE: Congressional Budget Office based on data from the Department of Energy.

NOTE: NTS = Nevada Test Site; NIF = National Ignition Facility; CFF = Contained Firing Facility; AHT = Advanced Hydrodynamic Test Facility.

a. Less than $5 million.

b. Negative numbers indicate increased costs.

Pros and Cons of Minimal Stewardship. Minimal stewardship generates the most heated debate of any of the alternatives illustrated here, perhaps because it challenges the science-based stewardship philosophy around which DOE and the laboratories have built their plans to maintain the stockpile under the CTBT. Critics contend that the minimal approach runs too many risks with the nation's nuclear deterrent. In the absence of underground testing, they argue, the weapons labs must learn as much as possible about how nuclear weapons work and age in order to preserve their reliability. A robust stewardship program is also essential for nuclear components, in their view, to certify components built with new materials or production processes. In some cases, new production methods will be required when DOE moves facilities as part of its consolidation effort. It may also discover new, less costly ways to produce items or ways to make them more reliable. And those components can only be verified, according to critics of minimal stewardship, if weapons scientists have the full range of experimental facilities that have been proposed by the department.

DOE objects to the approach presented in Alternative 4 because it argues that the testing capabilities that would be retained under such an option would be "inadequate to provide the data necessary to make the technical judgements" about whether an age-related problem requires remanufacturing a component, making a repair, or taking no action.[4] In essence, DOE argues that without the knowledge, skills, and data that the new facilities at the weapons laboratories and the Nevada Test Site will provide, weapons scientists will be unable to adequately assess the implications of defects that are uncovered by stockpile surveillance or to develop the proper solutions. That uncertainty makes it more likely that the United States will resume nuclear testing than under the Administration's plan, opponents of minimal stewardship contend, because the laboratories are more likely to lose confidence in the stockpile.

DOE also believes that a robust stewardship program with state-of-the-art facilities like NIF is essential for attracting talented new scientists to the laboratories in order to preserve the reliability of the stockpile. Supporters of science-based stewardship believe strongly that this alternative would not provide enough interesting work and so would fail to attract new talent.

Supporters of minimal stewardship challenge those assertions. They contend that under their approach, the United States would be able to retain confidence in its stockpile indefinitely. Nonnuclear components would be developed, tested, and manufactured in exactly the same ways that DOE plans. And all nuclear components would be subject to the same testing for manufacturing defects during production and assembly. Furthermore, the additional funding that Alternative 4 would provide for enhanced surveillance would permit age-related problems to be detected as early as possible. Improved codes would also be developed and validated using historical data from underground tests and data generated by existing facilities, although not with the level of detail that DOE intends.

The central difference between minimal stewardship and DOE's approach lies in what tools would be available to help determine the significance of age-related problems in the nuclear components (the primary and secondary). Critics of minimal stewardship argue that all of the experimental tools that the nation can afford should be available to help weapons scientists for that purpose. Advocates counter that the United States must use a priority-based approach in which investments are made in

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4. Department of Energy, *Draft Programmatic Environmental Impact Statement for Stockpile Stewardship and Management*, vol. 1 (February 1996), p. 3-7.

those facilities that address the greatest needs. Many of the new facilities are costly and unnecessary, they contend. Proponents of minimal stewardship argue that the primary—the nuclear component that is most likely to develop problems—would receive as much attention under their approach as in DOE's plans. If an age-related problem was suspected, testing at DARHT or other Los Alamos facilities would allow some analysis of the effect on reliability. If the problem could not be addressed through testing, new components would be manufactured to replace the aging ones.

Advocates also contend that the reliability of secondaries could be maintained under minimal stewardship. First, they argue, problems in the secondary are far less common and could be detected by inspection. Even if problems did occur, they would not be likely to lead to a total failure of the weapon, just a reduction in yield that would not affect the United States' nuclear deterrent, in their view. If the laboratories ultimately could not determine what effect an age-related problem would have, DOE could replace the aging secondary or radiation case with a new one. Second, supporters of a minimal stewardship approach argue, it is not clear that the expensive new machines proposed by DOE would be able to resolve many of the most important questions about aging.

Advocates of minimal stewardship also contend that DOE's quest for understanding as much as possible about weapons physics sends a signal to nonnuclear nations that the United States intends to continue designing new weapons, which they consider to be contrary to the spirit of the CTBT. Even if DOE has no intention of designing new weapons, they argue, the perception of such a capability may make it difficult to convince nonnuclear countries that the United States has really given up testing. Those countries are the ones from whom the United States would like continuing support for the Nuclear Non-Proliferation Treaty and ratification of the Comprehensive Test Ban Treaty. Indeed, one of India's primary complaints about the CTBT is that the nations with nuclear weapons are planning to continue designing new weapons and improving their arsenals. India cites NIF and other DOE stewardship efforts as evidence to support its case. Instead, proponents of minimal stewardship say, the United States should demonstrate its commitment to the CTBT by eliminating enough weapons-design capability (people and test facilities) to make developing new weapons difficult without access to underground testing. And it should not inflame concerns by building facilities beyond its needs.

GLOSSARY

Accelerator Production of Tritium (APT): The accelerator that the Department of Energy is developing to produce tritium. It will be built at the Savannah River Site in South Carolina if the Department of Energy decides to go forward with the project in 1998. Otherwise, DOE will use a commercial nuclear reactor to produce tritium, either purchasing one from a utility or leasing space in one operated by a utility.

boosting: The process by which tritium and deuterium are used to increase the output of the primary in a nuclear weapon. Boosting is used in U.S. weapons to reduce their size and weight.

Comprehensive Test Ban Treaty (CTBT): A treaty that would ban all tests of nuclear weapons that produce a nuclear yield. The treaty was approved by the United Nations General Assembly on September 10, 1996, and signed by President Clinton 14 days later. The treaty has not yet been submitted to the U.S. Senate for ratification. It will go into force when the 44 countries that now possess nuclear reactors or nuclear weapons have ratified it.

fissile material: Any nuclear material (usually the isotope of plutonium with an atomic mass of 239 or uranium with an atomic mass of 235) that can cause itself to fission rapidly—undergo a chain reaction—when enough material is brought together.

fission: The process that occurs when the nucleus of an atom splits into two or more pieces, releasing large amounts of energy. Fission generally also releases neutrons, which may strike the nuclei of neighboring atoms, causing them to split.

fusion: The process by which the nuclei of two light atoms fuse and release large amounts of energy. Fusion requires high temperatures and pressures to occur.

hydrodynamic test: A test that scientists use to examine how the pit in a nuclear weapon implodes as the high explosives surrounding it are detonated. A hydrodynamic test facility uses X rays to make images of the pit during implosion; it can be used to study how aging might affect the performance of the explosives and the pit. Weapons scientists substitute the plutonium pit with one made of different materials so that no nuclear reaction occurs and no nuclear yield results.

hydronuclear test: A hydrodynamic test in which the pit is allowed to produce a very small nuclear yield, enough to let weapons scientists study the initial phases of the reaction. The nuclear yield is equivalent to a few pounds of conventional explosive and is only a fraction of the size of the explosives that detonate the primary. The "zero-yield" provision of the Comprehensive Test Ban Treaty would make such tests illegal.

isotope: A variety of an element. The atoms of many elements (the element is determined by the number of protons in the nucleus) can have several different isotopes, in which the number of neutrons in the nucleus varies.

kiloton: A measure of the explosive power (or yield) of a nuclear weapon. One kiloton is equivalent to 1,000 tons of TNT.

megaton: A measure of the explosive power (or yield) of a nuclear weapon. One megaton is equivalent to 1 million tons of TNT or 1,000 kilotons.

National Ignition Facility (NIF): A facility that DOE will use to study the fusion reactions within a nuclear weapon. It will use a large laser to create some of the high temperature and pressure conditions found in an exploding weapon.

pit: A spherical shell of plutonium or highly enriched uranium that is used in the primary of a thermonuclear weapon. The pit is compressed by the high explosives that surround it until enough plutonium is brought together that it initiates a nuclear chain reaction.

plutonium: An element that has 94 protons and between 138 and 152 neutrons in its nucleus. Plutonium 239 (the isotope that has 145 neutrons) is the isotope generally used in the primaries of nuclear weapons.

primary and secondary: A modern thermonuclear weapon (also known as a hydrogen bomb) consists of a primary and a secondary. The primary uses fission (the splitting of plutonium or uranium atoms) to create enough energy to start the fusion reaction in the secondary.

stockpile: The United States' collection of nuclear weapons. The active stockpile includes all those weapons that are supplied with tritium and ready to be used. Most of the active stockpile is deployed with the Defense Department's nuclear forces. The inactive stockpile includes all those other weapons that DOE keeps in case it needs them or their components to replace parts of the active stockpile that may develop problems over time. Those weapons are not supplied with tritium.

stockpile management: DOE's long-term program to support the stockpile after a Comprehensive Test Ban Treaty through surveillance, maintenance, and production.

stockpile stewardship: DOE's long-term program to maintain the performance, reliability, and safety of the stockpile after a Comprehensive Test Ban Treaty through research and nonnuclear testing. The program will be carried out by DOE's weapons laboratories.

tritium: A radioactive isotope of hydrogen that has two extra neutrons in the nucleus. Tritium is used to boost the effectiveness of the fission reaction in the primary.

uranium: An element that has 92 protons and between 135 and 148 neutrons in its nucleus. Uranium 235 (the isotope that has 143 neutrons) is the isotope that is sometimes used in the primaries of nuclear weapons. Uranium 238 is used in the secondary and in the radiation case that encloses the primary and secondary to increase the yield of a weapon.

yield: The explosive power of a nuclear weapon, often expressed in tons or thousands of tons of TNT.