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Managing the Nation's Nuclear Materials: The 2025 Vision for the Department of Energy

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1.0 Overview

Decisions made about the nuclear materials complex in the near-term will have long-term consequences. To assess how best to integrate management decisions involving nuclear materials, we need to define and analyze a set of working assumptions about the long-term requirements of the nuclear materials complex. The time horizon used for the analysis is 2025, primarily because the analysis is intended to look beyond the constraints of the current set of facility investments and instead to focus on the mission requirements for the future. In doing so, it is possible to consider what new functional activities are needed to support the nuclear infrastructure and thereby provide guidance for investments over the next 25 years.

The core assumption is that evolution from the Department of Energy (DOE) of today to the DOE of the future must proceed in a way that preserves national security, bolsters economic prosperity, and promotes US policies. As stated in a 1998 White House Report, *National Security Strategy for a New Century*, "our strategic approach recognizes that we must lead abroad if we are to be secure at home."[1] The United States (US) must ensure the safety and continued welfare of its citizens while leading efforts to increase international stability. A modern and efficient nuclear materials complex will ensure US leadership in the nuclear arena and allow us to continue our pursuit of new scientific frontiers.

From this core assumption follow other assumptions about DOE's mission in 2025:

- Nuclear weapons will be essential to the security of the US
- Arms control and nuclear nonproliferation programs will be critical to world stability.
- Nuclear energy will be a viable energy option.
- Nuclear propulsion will continue as a naval application.
- Continuing scientific and medical research will be needed.
- Environmental stewardship will remain an enduring mission.

These assumptions can be elaborated as follows:

- A viable, but smaller, nuclear weapons complex supports an effective nuclear deterrent.
- Arms control efforts reduce the risk of nuclear conflict.
- Nonproliferation initiatives reduce the risk of nuclear threats, remain a high-priority national security requirement, and will be an integral element of our relations with other countries.
- Nuclear energy sources provide safe, efficient, clean power.
- A geologic repository provides permanent, safe disposal for spent fuel, high-level waste (HLW), and immobilized plutonium.
- New technologies help solve the problem of the "back-end of the spent fuel cycle."

To define the future, we began by examining the seven DOE mission areas in which nuclear materials are expected to be critical, as they will drive decisions on the use or disposition of nuclear materials. By analyzing Department goals and objectives for each individual mission area, we identified the nuclear materials and functions that will be needed in the future. We defined the range of functional capabilities required for the complex. The integration of missions then allowed for a cross-program look at the full suite of DOE missions. These were then analyzed utilizing various scenarios as a basis for balancing the mission set. These scenarios were projected from current US policies, international treaties and agreements, and reasonable assumptions about future directions. The balance of this report provides a discussion of the analysis, together with an executive summary of the results.

2.0 Executive Summary

A review of all documentation relating to the long-term suitability of missions within the Department has been performed, to include Presidential Decision Directives, Secretary of Energy Directives, Congressional actions, Department of Defense requirements, International agreements and treaties, Departmental advisory group assessments, National interest group assessments, and others. Based on scenario analysis and addressing all of the Department's future missions and functional requirements, it is concluded that a modern and efficient nuclear material management complex, comprised of the critical functions noted, will be required. This has been determined to be critical to the security, economy, and welfare of the United States. This review was conducted to get a national, as well as a Departmental, perspective of the future missions of the Department.

After review of this body of documentation, the first conclusion drawn from the policy and intent of the United States is that the entire suite of DOE missions that involve to do with nuclear materials is intended to continue at some reasonable level of support. This conclusion includes a continuation of nuclear defense, arms control, nonproliferation, nuclear energy, environmental response, nuclear science and medicine, and Naval Reactors.

Conclusions

1. The US policy is to continue with current missions involving nuclear materials beyond 2025.
2. Each mission area must plan for great uncertainty in scope, capacity, and technology needs.
3. Significant interrelationships exist within and between mission areas, making each dependent on the others' skills, equipment, facilities, capability, and capacity.
4. The primary nuclear material production and handling functions are very inter-linked and critical to overall Department success. These functions will remain a relative constant, but will need to be utilized by multiple programs for various missions, perhaps even simultaneously. Redundancy will not exist and, therefore, each function will need to be robust and of fairly significant capacity.
5. On an international level, nuclear material issues are very broad and different with each country. In order to provide leadership internationally, the Department must retain competence in nuclear materials, energy, defense, science, space, medicine, and nonproliferation.

In reviewing each of the various documents, it is clear that great uncertainty exists as to the full scope and capacity requirements for each of the various missions. These are primarily driven by uncertainty in international agreements but are also driven by budget uncertainty, stakeholder issues, knowledge based on material aging and state of technology, and marketplace demands. The second conclusion is therefore that each of the mission areas must plan for an uncertain future with broad ranges of scope and capacity. In addition, each mission must plan for technology development programs capable of addressing a wide range of future missions.

There are clear interrelationships both within and between the missions of the Department. For example, in the defense mission, the Comprehensive Test Ban Treaty (CTBT) [2] allowed the cessation of nuclear testing but required that the Science-Based Stockpile Stewardship (SBSS) program grow in order to provide certification of the stockpile. Strategic Arm Reduction Treaties (START) [3] which allow for shrinking the stockpiles, will result in a growth of the arms control and disposition activities. Concern over greenhouse gas emissions in the environment is creating a renewed interest in nuclear power. Interest in reducing stockpiles in Russia is creating a shift away from direct disposal of plutonium to one of processing/purification of excess plutonium for barter purposes.

There are many other interrelationships that create dependencies between missions. An example is the transportation function, where packaging, shipping containers, and transportation systems are simultaneously needed for weapons, materials, waste, and energy products. Safeguards needs for all missions rely on the technology developed for nonproliferation purposes. Another example is storage, where materials for DOE Office of Defense Programs must be retained but where excess materials are occupying critical storage space. Insufficient excess capacity exists to allow for temporary storage at sites. Yet another example is the availability of plutonium handling space where defense, energy, arms control, and nonproliferation programs need critical project space within the same facilities at the same time. The third conclusion is therefore that significant interrelationships exist within and between mission areas, making each dependent on the other’s skills, equipment, facilities, capability, and capacity.

The fourth conclusion addresses critical functions. The functions include irradiation, separations, fabrication, processing, monitoring, disposal, storage, and material science. Every mission area is dependent on each function in some fashion. When evaluating the ranges of missions, it is interesting to note that emphasis on a function within a mission will vary but that emphasis across all missions does not significantly vary. This indicates that the functions represent aspects of a system and that without each function the system will seriously suffer or even fail. Therefore, the fourth conclusion is that the primary nuclear material production and handling functions are very interlinked and critical to overall Department success. The functions will remain a relative constant, but must be utilized by multiple programs for various missions, perhaps even simultaneously. Redundancy will not exist and therefore each function must be robust and of fairly significant capacity.

The fifth conclusion addresses the position that the US fills in the international arena. Each country has different policies and programs involving nuclear materials. For instance, France is very concerned about energy security and produces ~80% of its electricity from nuclear reactors. [ref] They practice reprocessing and, as a result, do not retain legacy waste problems. They are less concerned about nonproliferation concerns and rely on the US to address this issue. The Russians view their nuclear materials as assets and as a positive legacy for the future. They fully intend to burn plutonium as mixed oxide (MOX) fuel [ref] and do not intend to discard any material to repositories. They commingle defense and domestic nuclear power and therefore continue to produce weapon-usable plutonium while simultaneously producing domestic power. For the US to provide international leadership in nuclear issues, it must acknowledge that these differences in policy and approach exist and then be prepared to participate in discussions on nuclear material and technology issues. To do this, the Department must retain strong competence in nuclear materials technologies that support defense, energy, space exploration, arms control, nonproliferation, science, and medicine.

In summary, the US invested in a significant suite of facilities in the late 1940s and 1950s. These facilities have provided the foundation for the development of nuclear technologies for the past

50 years. These facilities have reached or are approaching the end of their useful lives. Some are simply obsolete and no longer usable. Some are not appropriately sized for the emerging missions and are therefore very expensive to retain. Some cannot meet current operating standards in terms of safety, security, and environmental protection. Mission success will be strongly dependent on healthy facilities and infrastructures. Therefore, the overall conclusion is that independent of discrete missions, the Department will need a very robust, modern, technically flexible, and integrated suite of functions and facilities in order to achieve mission success. Sharing of functions and facilities will likely be essential.

3.0 Background

Advanced planning deals with the development of a vision for the DOE complex for the year 2025 and beyond. For this report, the 2025 vision discusses attributes of the future complex from a policy and mission perspective. The US must plan for an uncertain future that may require a significant stockpile or one with fewer nuclear weapons. Likewise, we must plan for broad-range management for excess nuclear materials. We must plan for the construction of modern and more flexible facilities while simultaneously managing the cleanup of Cold War legacy materials, facilities, and waste. Finally, we must plan for an uncertain future for nuclear energy, science, and medicine with the knowledge that the United States must be a significant international contributor to nuclear material science if we are to play a role in international nonproliferation, arms control, and nuclear science. As the US government agency with the primary responsibility for nuclear materials, the Department must manage this transition and lead with a vision and a consistent program. In this regard, stewardship of nuclear materials is the companion of a nuclear weapon SBSS program. With an integrated strategy for nuclear materials management, DOE can simultaneously maintain a leadership position in international nuclear materials discussions as well as develop more comprehensive and cost-effective programs on a domestic level.

Since the end of the Cold War, the US and the world have witnessed a policy shift in national security programs from “arms build-up” to “stockpile reduction, arms control, and nonproliferation.” In addition, the Balanced Budget Agreement between the President and Congress [26] imposed constraints on funding availability, resulting in the need to improve efficiencies and to reconsider cost-effectiveness and built-in redundancy. These factors create a challenge to the US to maintain a viable national security profile in addition to maintaining leadership positions in nonproliferation, arms control, nuclear energy, environment, medicine, and science.

In the recent past, most DOE planning was done by field/program offices to address specific near-term programmatic requirements. Often, these programmatic requirements have been driven by budget constraints. The task of managing the nation’s nuclear material inventory and the many DOE nuclear facilities is large and complex and is becoming increasingly difficult as the facilities reach the end of their useful lives. Therefore, a longer-range, corporate-level planning process will provide a vehicle to promote integration of nuclear management functions, assure cost-effective reinvestment in future facilities, and coordinate and streamline the many ongoing efforts to manage current facilities and infrastructure. Most importantly, the planning process will help to establish the needed infrastructure for the complex. This planning will also help to avoid independently derived decisions that have profound adverse impact across other missions.

With regard to the status of DOE facilities by 2025, essentially all of the nuclear facilities in the current DOE Complex will be in excess of 70 years old. This 25-year horizon, between now and 2025, is not long with regard to new facility acquisition, considering the time required for the National Environmental Policy Act process, site selection, budget authorization, design, construction, and start-up. There is little lag-time available if the Department is to acquire the needed modern capabilities and capacities for 2025. The Nation must begin planning a new nuclear material management complex now in order to accomplish the identified future missions. There will be many opportunities to consider facility designs to maximize possible uses of these new facilities and select sites to improve efficiency and protect our workers, the public, and environment.

Bridging near-term plans to the 2025 Vision requires a shift in planning perspective from a relatively well-defined, site-specific view of facility requirements (near-term) to a less-well-defined, non-site-specific view of functional requirements (2025 Vision). Based on the identified functional requirements, a qualitative assessment is made with respect to the size and type of facility capabilities required. Therefore, facility considerations in the 2025 timeframe are only discussed in terms of functions that need to be performed. Specific facility siting and designs are not germane to this study.

One issue that is identified as a guiding principle for evaluating the 2025 Vision is that of the *Imperative of Engagement* [1]. The *Imperative of Engagement* recognizes that “we must lead abroad if we are to be secure at home, but we cannot lead abroad unless we are strong at home.” While there is flexibility for determining the size of the complex that will be supported in 2025, the US will have to stay engaged in defense and non-defense nuclear missions regardless of whether we follow a policy of disengagement or leadership. This perspective is driven largely from a defense standpoint, where international commercial nuclear energy generation creates a proliferation concern. In addition, the US must remain engaged in existing arms control treaties and nonproliferation activities to assure the safe, secure, and legitimate use of nuclear materials.

4.0 Analysis Approach

Because of changing mission requirements, a smaller, more modern nuclear material management complex will be needed to perform missions critical to the Nation’s interests. The purpose of planning for the 2025 Vision is to properly define the appropriate mission space and to develop a program that addresses future needs. The end result of this planning will be the identification of the DOE functional capabilities required for addressing the stated 2025 Vision. This process, from articulating the 2025 Vision to defining the 2025 functional capability requirements, is illustrated in Figure 1.

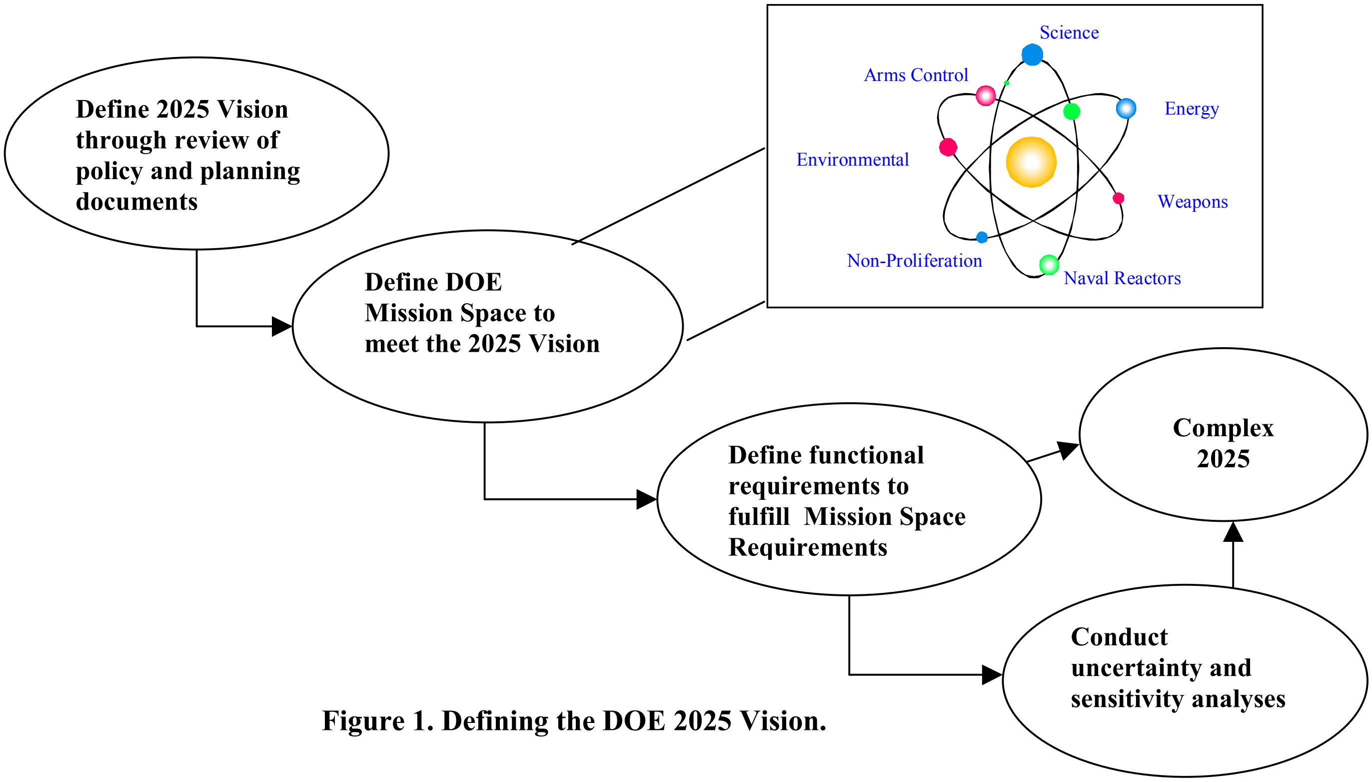


Figure 1. Defining the DOE 2025 Vision.

5.0 2025 Vision for DOE

The first step in the process outlined in Figure 1 is to define the 2025 DOE mission space by reviewing existing US and DOE policy and strategic documents. This provides a basis for identifying elements of the 2025 Vision. Much work has already been done to define the US national defense posture and ensure energy security for the 21st Century. DOE and all of its programs have also developed strategic plans, in accordance with the Government Performance and Results Act [4], which define the vision for DOE and its programs. "Road maps" have been developed for the four major business areas of DOE to define research and development activities to guide the Department in achieving its national defense, environmental protection, energy security, and economic objectives [12,13,15, 24]. These strategy and program documents provide the necessary support for defining the DOE complex 2025 Vision.

Some of the documents that have been reviewed and the main vision points that have been articulated are listed in Table 1.

Table 1. Policies and plans shaping the future complex

Planning Document	**Highlights**

***A National Security Strategy For a New Century* [1]**	• Core objectives
	  • Enhance our security
	  • Bolster America's economic prosperity
	  • Promote democracy abroad
	• Imperative of Engagement
	  • Lead abroad if we are to be secure at home

Report to the President on Federal Energy Research & Development for the Challenges of The Twenty-first Century [5]

- "…for reasons of economy, environment, security, and stature as a world power alike, the United States must maintain its leadership in the science and technology of energy supply and use."
- "To write fission off now…would be imprudent in energy terms and would risk losing much US influence over the safety and proliferation resistance of nuclear energy activities in other countries."
- Focused R&D needed to address economic, safety, waste, and proliferation issues

National Defense University
"US Nuclear Policy in the 21st Century" [6]

- Nuclear weapons will continue indefinitely to play an indispensable role in US national security policy.
- The US requires a credible nuclear deterrent posture, a fundamental challenge in the absence of underground testing.
- Dormant elements of the nuclear force must be reconstituted.

"Transforming Defense National Security in the 21st Century"
[7]

- Implications of the world in 2020
  - **Hedge** against uncertainty
  - **Curtail** the outdated/less useful
  - **Explore** new concepts
  - **Adapt** over time
- Recommendation on sea forces
  - Move toward small signature ships capable of providing sustained long-range, precision firepower
- Recommendation on strategic forces
  - Maintain support for Cooperative Threat Reduction programs
  - Move to START II as soon as possible
  - Complete defense systems with arms control agreements
  - Sustain SBSS program to support CTBT

Presidential Decision Directive
(PDD)-13 [8]

- Cease production of fissile materials for weapons use
- Eliminate excess fissile materials
- Draw down stockpiles
- Strengthen international cooperation

Prepared Remarks by US Secretary of Energy, Bill Richardson *[9]*	• Six legacies from the first five decades of the nuclear century were addressed: – Nuclear arsenals that are still far too large – Vast amounts of fissile material from nuclear weapon reductions that need to be controlled – Nuclear weapon production complexes that must be redirected to peaceful ends – Proliferation concerns in Iraq and North Korea that must be resolved – Final disposition for the fuel cycle's back-end, assuring the safe use of nuclear power – The reservoir of peaceful, humanitarian applications of the atom still to be tapped
Prepared Remarks by US Secretary of Energy, Bill Richardson *[10]*	• IAEA can play a role in preventing a return of the nuclear arms race • An agenda for the future is built on Four Pillars for nuclear peace, security, and safety: 1. Preserving the nonproliferation treaty regime 2. Controlling nuclear materials 3. Promoting the safe use of nuclear power 4. Managing the back-end of the nuclear fuel cycle
Stockpile Stewardship Program: 30-Day Review [11]	• Policy of not conducting nuclear tests will continue • Must ensure that the nuclear stockpile remains safe, secure, and reliable • The US nuclear deterrent remains a supreme national interest
Research and Development Portfolio, Energy Resources [12]	• Ensure reliable and diverse energy supply • Ensure clean and affordable power • Increase the efficiency and productivity of energy use
Research and Development Portfolio, Science Resources [13]	• Support vital science infrastructure • Maintain and build required core competencies • Support a balanced portfolio across the continuum of science
"The Green Book" (1999) [14]	• Maintain reliability of the nuclear weapons stockpile without testing • Ensure the vitality of the national security enterprise • Actively work on arms control and nonproliferation • Reduce nuclear weapons stockpiles • Maintain the national security requirements for naval propulsion

Research and Development Portfolio, Environmental Quality Resources [15]	• Reduce the most serious risks from the environmental legacy • Clean up as many as possible of the 83 remaining contaminated sites by 2006 • Safely dispose of nuclear waste

Based on this review, consistent themes can be identified, providing guidance to defining the DOE's 2025 Nuclear Vision. The 2025 Nuclear Vision includes the core elements, as follows:

The 2025 Nuclear Vision: The Department of Energy recognizes that nuclear materials and the ability to manage them are critical to the security, economy, and welfare of the nation and envision, through leadership in science and technology, to continued advancement of US energy, environmental stewardship, and national security by

- Deploying a smaller robust, nuclear weapons complex that provides a nuclear deterrent.
- Reducing global nuclear danger through national security, nuclear safety, and arms control activities.
- Increasing international security through nonproliferation policy and technology deployment
- Being a key contributor to ensure that the US has flexible, clean, efficient, and accessible energy supply with minimal vulnerability to disruption.
- Solving the back end of the nuclear fuel cycle problem.
- Being a world leader in environmental restoration, nuclear materials stabilization, waste management, facility decommissioning, and pollution prevention.
- Improving nuclear materials management
- Building core competencies to support a vital science infrastructure

This 2025 Nuclear Vision is also consistent with the DOE Vision, as articulated in the US Department of Energy Draft Strategic Plan.

The DOE Vision

We aspire to achieve the following vision:

The Department of Energy, through its leadership in science and technology, will continue to advance US energy, environmental, economic, and national nuclear security by being:

- A key contributor to ensure that the United states has a flexible, clean, efficient, and accessible system of energy supply and with minimal vulnerability to disruption.
- A vital contributor to reducing the global nuclear danger through its national security, nuclear safety, and nonproliferation activities.
- A world leader in environmental restoration, nuclear materials stabilization, waste management, facilities decommissioning, and pollution prevention.
- A major partner in world class science and technology through its National Laboratories, research centers, university research, and its educational and information dissemination programs.
- A safe and secure workplace that is recognized for management excellence, nurtures creativity, is trusted, and delivers results.

6.0 Mission Analysis

Based on the above discussion, a mission space can be identified for the DOE in 2025 that will properly envelope the core elements identified above. The following seven mission areas define this mission space.

- Nuclear Weapons: Maintain sufficient nuclear weapons and infrastructure for national defense.
- Arms Control: Reduce worldwide stockpile of nuclear weapons.
- Nonproliferation: Prevent spread of nuclear materials and weapons
- Nuclear Energy: Ensure nuclear energy as a dimension of a viable energy future
- Environment: Treat remaining legacy materials, facilities, and waste
- Science: Preserve and supply nuclear materials for future scientific, defense, and medical research, development, and other needs.
- Naval Propulsion: Ensure adequate supply of highly enriched uranium (HEU) and testing capabilities.

These seven mission areas represent the basis for evaluating DOE functional needs, and therefore infrastructure investment needs, for the Department's future. The approach for analyzing the functional and facility requirements is outlined in Figure 2, below. The following sections provide the detailed analysis for this approach.

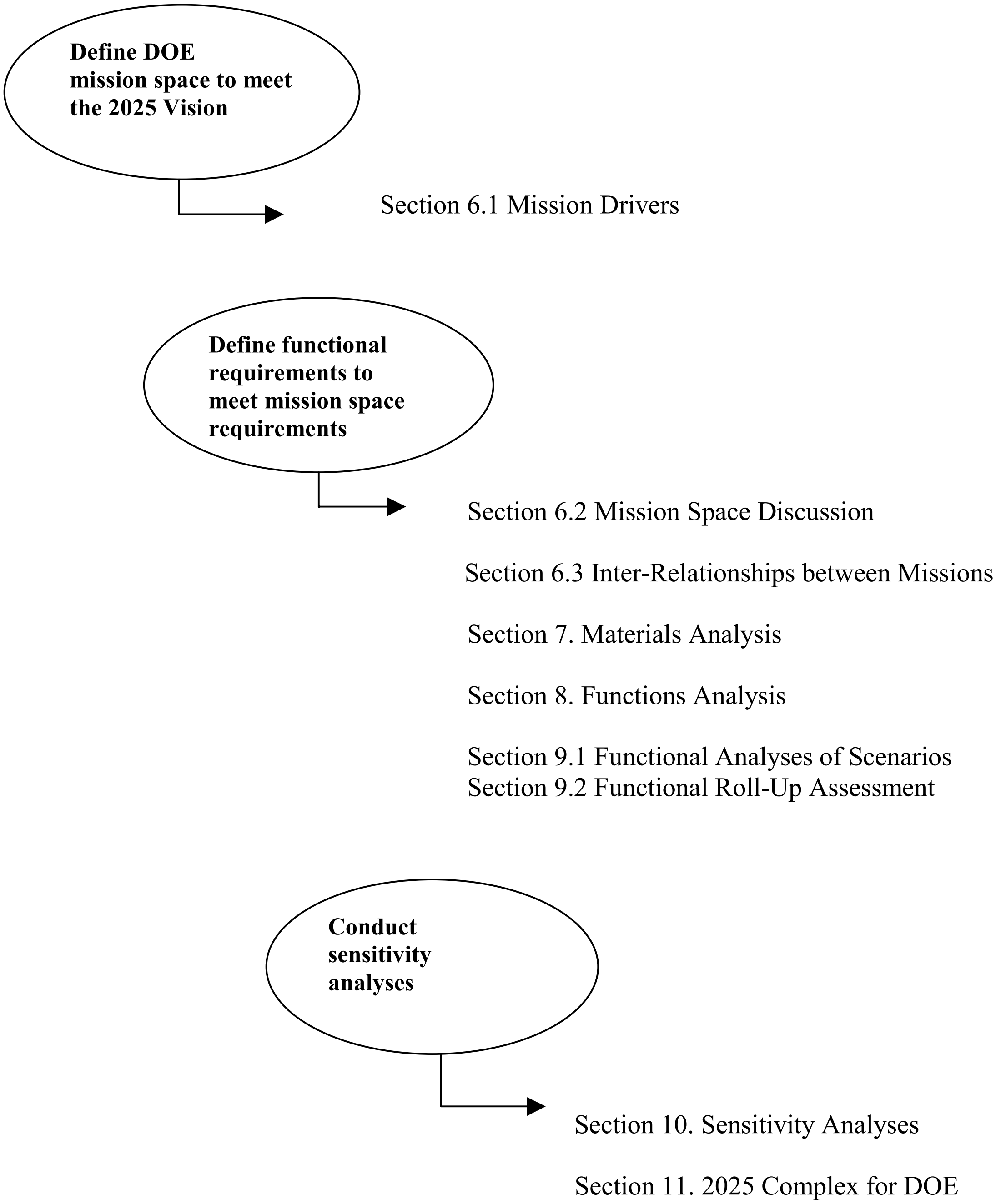


Figure 2. Process to determine 2025 Vision facility requirements

6.1 Mission Drivers

Given these seven missions, it is important to recognize US policy and external influences that will drive future DOE missions. Some of the more important drivers that will shape the seven mission spaces are discussed in the following section. The drivers have been grouped according to whether they relate to national security issues or non-defense issues.

National Security [27]

As discussed in many of the defense readiness studies, nuclear weapons are essential for US security. With the need for nuclear weapons as a given, there are four important drivers:

- Nonproliferation Treaty (NPT) [16]
- Strategic Arms Reduction Treaties (START) [3]
- Comprehensive Test Ban Treaty (CTBT) [2]
- Bilateral agreement related on disposition of weapon-capable fissile materials [17]

6.1.1.1 Nonproliferation Treaty [16]. The NPT was signed by the United States, the USSR, the United Kingdom, and 59 other countries in July 1, 1968, and it entered into force on March 5, 1970. The NPT recognizes states that exploded nuclear weapons before January 1967 as nuclear weapon states, namely the US, the United Kingdom, Russia, France, and China. All other member states are recognized as non-nuclear weapon states. NPT provisions include the following: (1) nuclear weapon states may not transfer nuclear weapons to non-nuclear weapons states or assist a non-nuclear weapon state in acquiring nuclear weapons, and (2) non-nuclear weapons states may not manufacture or acquire nuclear weapons and must accept IAEA safeguards to prevent diversion of fissionable materials to weapons uses. Now, 178 nations are members, with France and China joining in 1992.

Since the 1970s, nations have negotiated safeguards agreements with the IAEA, and safeguards inspections have been carried out routinely at many declared non-weapon sites. India, Pakistan, and Israel have not signed the NPT.

6.1.1.2 Strategic Arms Reduction Treaties [3]. The importance of the START treaties in the context of this report is that they lead to progressively smaller nuclear weapons stockpiles, and consequently, to larger surpluses of fissile material that must be dispositioned in a manner that assures arms reduction agreements are met.

The first of these treaties, START I, was signed by the US and USSR on July 31, 1991. The treaty reduces deployed strategic delivery vehicles from about 2,500 to 1,600 for each side and reduces the strategically deployed warheads that are accountable from about 10,200 to 6,000 for each side. The treaty also includes a comprehensive set of data exchange, notification, verification, and on-site inspection procedures. The treaty is designed to reduce the number of most threatening deployments capable of a first strike. Beginning in December 1991, the USSR broke up into 15 independent republics. Four of these republics (Russia, Kazakhstan, Belarus, and Ukraine) contained the strategic nuclear forces covered by START I. In a May 1992 protocol, these four states agreed to assume the START I obligations of the USSR. Kazakhstan, Belarus, and Ukraine further pledged to become non-nuclear weapons parties to the NPT. On December 5, 1994, in Budapest, Hungary, President Clinton and the presidents of Russia, Ukraine, Belarus, and Kazakhstan met and jointly signed the final necessary documents, and START I finally entered into force.

In 1992, the US and Russian presidents signed a "Joint Understanding on Reductions in Strategic Offensive Arms." This Joint Understanding called for the US and Russia to sign a second treaty, based on START I, which would further reduce strategic nuclear deployments. This agreement (to be called START II) called for major reductions, in two phases, to an aggregate total of no more than 3,500 strategic warheads, and for the elimination of all multiple independently targetable re-entry vehicles (MIRV) intercontinental ballistic missiles (ICBMs) by 2003. This treaty would employ START I procedures for notification, elimination, and verification. In September 1997, the US and Russia signed amendments to the START II treaty. These amendments included a START II protocol to extend the completion date for START II elimination and reductions and to extend the date by which the interim limitations and reductions (Phase I) of START II must be carried out. The agreement also stated that the US Congress and the Russian Duma would be required to approve the START II provisions before they would be in-force. This full approval has not yet been obtained.

In March 1997, discussions between the US and Russia began on a new treaty, START III. This proposed new treaty would reduce the total number of allowed deployed strategic warheads to values below 2,500 to alleviate Russian concerns over alleged START II asymmetries. Negotiations pertaining to START III issues are ongoing at this time.

6.1.1.3 Comprehensive Test Ban Treaty [2]. The CTBT, which was signed by the President in 1996 and submitted to the US Senate for ratification on September 23, 1997, prohibits nuclear testing unless the involved State Party invokes the "supreme national interest" clause and withdraws from the Treaty. The US Senate declined to ratify the CTBT. However, the President stated on October 13, 1999, that the US would continue the policy of not conducting nuclear tests. The challenge to the Department is to maintain the US nuclear deterrent without nuclear testing. This challenge is now met through the Science-based Stockpile Stewardship Program and attested to via annual testimony by the national laboratory directors to the United States Congress. The Department has instituted the SBSS to meet this challenge and manage the associated risks of maintaining the nuclear weapons stockpile without additional nuclear testing. The SBSS is an active program of surveillance, testing, assessment, refurbishment, and certification of the stockpile. It is dependent on a highly integrated and interdependent program of experimentation, simulation, and modeling that is consistent with the understanding and the archived database developed under the nuclear test program.

An impediment to the final entry-into-force of the CTBT has been the failure of the Russian Duma to ratify START II. Without a START II treaty and further stockpile reductions, some may feel the need for the US to maintain further flexibility (including nuclear tests) to maintain its deterrent posture with a greatly reduced stockpile. The recent set of five nuclear tests by India in May 1998, and the subsequent nuclear tests by Pakistan within a few days, has raised uncertainties about the CTBT's future. According to Article XIV, the CTBT cannot enter into force without the accession of the threshold states of India, Pakistan, and Israel, as well as the nuclear weapon states (US, Russia, Britain, France, and China). By early 1999, the US had solicited promises from officials of both India and Pakistan to sign the CTBT. The signing of the CTBT and its implementation are important to the continued viability of the NPT.

6.1.1.4 Bilateral Agreements [17]. The US and Russia have several bilateral agreements regarding the management of surplus nuclear materials. In February 1993, the US and Russia signed an agreement to convert HEU resulting from dismantlement of Russian nuclear weapons into low-enriched uranium (LEU) for fuel in commercial nuclear reactors [17]. The agreement also established appropriate measures to fulfill the nonproliferation, physical security, material accounting and control, and environmental requirements with respect to HEU and LEU subject to the agreement. The US agreed to purchase from Russia LEU blended down from 500 tons of HEU removed from Soviet weapons. (Theoretically, a crude nuclear device can be produced from as little as 25 kilograms of HEU.)

In November 1996, the US and Russia reached a new agreement to accelerate the pace of the 1993 HEU agreement [17]. The agreement also provides for a 50 percent increase in the amount of LEU that the US will receive in the subsequent five years. By the year 2001, Russia is expected to convert the HEU equivalent of about 7,500 nuclear warheads to LEU. The US Enrichment Corporation is the US government's agent for the purchase agreement.

There have been several agreements between the US and Russia and statements by the presidents of the two countries in the past five years related to the removal of plutonium from nuclear weapons [17]. In March 1995, President Clinton stated that 200 tons of fissile material would be withdrawn from the US stockpile and never used again for weapons, and that this material would be voluntarily offered for IAEA safeguards. In September 1997, the Russian President stated that up to 500 tons of HEU and up to 50 tons of plutonium would be removed from nuclear military programs. In September 1998, the two presidents signed a "Joint Statement of Principles for Management and Disposition of Plutonium Designated as No Longer Required for Defense Purposes." This statement affirmed the intention of each country to negotiate an agreement to remove approximately 50 tons of plutonium from nuclear weapons programs and to convert this material into forms unusable for nuclear weapons. Two methods for converting this material were allowed in the agreement: reactor irradiation in existing reactors and immobilization with high-level waste. Conversion rates of at least 2 tons/year are to be achieved by no later than 2008 and rates of at least 4 tons/year are to be achieved as soon as possible thereafter.

Defense readiness studies also identified the continuing need for a viable nuclear submarine fleet. This means that DOE will ensure availability of HEU to fuel the propulsion systems, and irradiation capability to perform needed materials and other testing, to ensure proper operations of these systems.

6.1.2 Non-defense

The drivers for non-defense DOE missions are the government policies regarding peaceful uses of nuclear energy, including production of medical and industrial isotopes and isotopes for civilian space missions. Congress authorized these missions for the Atomic Energy Commission and its successor organizations in the Atomic Energy Act of 1946 [18].

6.1.2.1 Commercial nuclear power. Federal government support for the development of a viable commercial nuclear power industry has been a major driver in DOE's energy and nonproliferation missions in the past. As the first generation US nuclear industry has now matured, perceived changes in public support for nuclear power have led to a decline in government support in recent years. As part of the commercial power driver, the Nuclear Waste Policy Act [19] and its amendments focus much of DOE's energy work toward solving the disposal issue for commercial spent fuel. As the nation's perspective on future energy need changes over time, this could result in further change to government positions toward commercial nuclear power. These changes could range from privatization of all commercial nuclear power support functions to a return to a more vigorous nuclear power development program, to steer the development of the next global nuclear infrastructure. Some of the factors that could define future government policy toward commercial nuclear power include non-US development of advanced nuclear fuel cycles; safe, proliferation-resistant plutonium burners; growth in demand for electricity; the availability and cost of fossil fuel; responses to international treaties on greenhouse gas emissions; and the development of alternative energy sources.

6.1.2.2 Industrial/Medical Isotopes. The Federal government has been a major supporter of activities related to nuclear processes and a producer of nuclear isotopes for industrial, medical, and space missions since the enactment of the Atomic Energy Act of 1946. In Section 5 (c) of the Atomic Energy Act [18], Congress authorized the Atomic Energy Commission "… to distribute, with or without charge byproduct materials to applicants seeking such materials for research and development activity, medical therapy, industrial uses, or such useful applications as may be developed." The extent to which the government continues that policy in the future or promotes privatization of these activities will determine the importance of the Federal government in the management of nuclear materials for non-defense missions. Two factors that may affect the government role in this arena are the development of new technologies and treatments that use isotopes, public demand for these isotopes, and the availability of commercial or international sources of the isotopes. Currently, the US has an agreement with Russia and purchased 5 kilograms of plutonium-238 for use in US space missions. If the US could successfully expand this agreement and make other agreements with Russia and other countries to purchase isotopes, the need for government production of isotopes may be considerably reduced. The Nuclear Regulatory Commission (NRC) would regulate isotope production, transportation, storage, and disposal.

6.2 Mission Space

Given the mission drivers discussed, a detailed description of each mission area follows. The requirements for nuclear materials management in the year 2025 and beyond are dependent on the Department's missions between now and that time. Although many of these missions are expected to be similar to those of today, policy changes will result in variations in the size and importance of the DOE infrastructure and operations required for meeting these missions. To understand these requirements, it is necessary to examine future mission space for the Department as it relates to nuclear materials. As previously identified, the relevant missions are as follows:

- Nuclear weapons
- Arms control
- Nonproliferation
- Energy
- Environment
- Science
- Naval propulsion

The Department, in its goal of reducing global nuclear danger, has embraced the imperative to address the urgent security hazards posed by nuclear insecurity in the former Soviet Union, North Korea, and elsewhere. This requires a reinvestment/modernization in US nuclear infrastructure in order to remain technically credible in nuclear leadership in the 21st century. Incumbent in this reinvestment/modernization is the need to continue to invest in the critical technical competencies required to support the missions. These technical competencies include academic investments so as to provide the pipeline of trained personnel as well as the modern equipment needed for both personnel and missions. Elements of the future mission within the Department are described below.

6.2.1 Nuclear Weapons

Three critical factors will affect the scope of the nuclear weapons program in the future:

1. International agreements, treaties, etc. [24]
2. The aging of materials in the stockpile and the impact this has on rebuild rates. [24]
3. The capacity and capability of the complex to respond, technically, to stockpile needs to include redundancy. [24]

Treaties and agreements that have yet to be negotiated will affect the size of the future nuclear weapons complex. In addition, acceptable age of stockpile components will play a major role in determining the rebuild rates for the enduring stockpile. Two nuclear weapons annual production rates have been selected to describe reasonably large and small weapons production missions. The large nuclear weapons complex would have a production rate of about 500 weapons per year, whereas the small complex would have a production rate of 20 weapons per year [25]. The first represents a production rate that may support a nuclear weapons stockpile that is similar in size to today's stockpile, but where weapons systems are replaced periodically to overcome concerns over continued viability and/or safety of aging components. The second rate would support a stockpile where SBSS has assured the continued viability and safety of the existing stockpile, and replacements are required only for a small number of units that are removed from the stockpile for quality verification. Each of these cases has implications for the quantity of nuclear materials that are needed to support the stockpiles and the quantity of materials that would be in excess of weapon needs and thus available for disposition.

The smaller nuclear weapons stockpile, such as a stockpile that would result from further arms treaties, such as START II and START III, would require less plutonium and uranium for weapons. Consequently, additional plutonium and uranium could be declared excess to national security needs and could be transferred for disposition as MOX fuel or to other forms for disposal. The half-life of tritium is 12.33 years. Therefore, the US must maintain the capability to produce tritium. Current departmental plans for tritium supply, which include tritium production in Tennessee Valley Authority reactors and extraction in a new DOE facility, should be adequate to support either case.

The mission space for nuclear weapons is also defined by the facilities needed to support the future range of nuclear weapons production. A new plutonium pit fabrication facility would be needed to support a production mission of up to 500 units per year, but a facility to support a 20 pit per year production rate could be collocated with a plutonium research and development facility. The same holds true for uranium component production. Nuclear materials storage and processing facilities would also need to be sized appropriately for the respective component production rates.

The size of the supporting weapons production laboratories is driven by the scope of the SBSS program and is therefore relatively independent of the new nuclear weapons production rate. It is assumed for each case that nuclear testing would not be restarted and that the SBSS program would be similar for both cases to certify weapon performance and to predict changes that may adversely affect warhead safety or reliability. An argument could be made that the smaller stockpile would require a more rigorous SBSS program because successful certification of each remaining weapons system becomes critical. Special facilities and special isotopic materials will be needed for this SBSS program.

Finally the issue of redundancy must be addressed. Originally, some redundancy was established in the DOE Complex as a hedge against first-strike loss of capability and capacity. The country built redundant capacities for material production, weapon design, and component production. In recent years the country has abandoned this policy as a result of budget inadequacies and shifting priorities. Today, the stockpile is large and the rationale for physical redundancy of facilities no longer exists and therefore physical redundancy of facilities is no longer a dimension of the Department's Office of Defense Programs. But, in the same way that smaller experimental facilities have replaced Nevada Test Site for stockpile certification, intellectual redundancy must replace physical redundancy. SBSS is the manifestation of this shift in policy. Intellectual redundancy will require modern science facilities and tools to attract and retain the people necessary for future mission success.

6.2.2 Arms Control

The same treaties and agreements that affect the nuclear weapons mission will affect the Department's future arms control mission. The range of the mission space would be determined by the quantity of nuclear materials, such as plutonium and uranium, that would be declared excess to national defense needs. Current DOE plans [20] include the construction of three facilities: the Pit Disassembly and Conversion Facility (PDCF), a mixed oxide fuel fabrication facility (MOX), and a Plutonium Immobilization Plant (PIP). These facilities would be adequate to support a nuclear weapons stockpile under the START I treaty. Under the START III treaty, more plutonium and uranium would be available for disposition. These facilities could be operated for a longer period of time to accommodate this material or increased in size to accommodate a higher throughput. Additional storage capacity will likely be needed for the excess material until it can be dispositioned. A smaller nuclear weapons stockpile may also increase the quantity of uranium available for blending to make commercial nuclear fuel. Additional storage capacity may be needed to accommodate this material until it is transferred to the private sector. Decisions concerning storage must be made soon so that proper storage capacity can be provided.

A smaller nuclear weapons stockpile would also increase the quantity of waste materials requiring disposal. As more nuclear weapons become excess to national defense needs, more nuclear material would become available for disposition if it is not retained for national security purposes. These materials would be processed for disposition by immobilization, conversion to and irradiation of MOX fuel, or blended down for commercial uranium fuels. The additional waste generated during this processing would be disposed of in a geologic repository or waste disposal facility.

6.2.3 Nonproliferation

Nuclear policy in the US has evolved over the last five decades as a result of reactions to certain defining events. These events generally involved either safety issues or concerns about the potential proliferation of nuclear weapons.

The US approach to controlling the spread of nuclear weapons has undergone three significant changes over the last 50-plus years, each change arising in response to significant events in the evolution of global nuclear power. These policy changes are captured by the initial Atomic Energy Act, the Atoms for Peace Initiative [21], and the convergence of several events that occurred during the 1970s. With the end of the Cold War, a new global nuclear infrastructure is evolving that presents a very different challenge and our vision for and approaches to assuring safe, secure, and legitimate nuclear operations must change to meet this challenge.

The goals of President Eisenhower's Atoms for Peace Proposal were to

- Control the dissemination of nuclear information through active participation with other countries
- Establish a US advantage in commercial nuclear competition
- Force the USSR to divert materials from weapons to energy use
- Support the evolution of an International Atomic Energy Agency
- Nurture safety and proliferation prevention cultures worldwide
- Offset the negative impact of the hydrogen bomb

The Atoms for Peace initiative resulted in active R&D collaboration in the peaceful use of nuclear energy for the next 20 years. It resulted in the implementation of the IAEA concept of nuclear material safeguards. The US trained most of the nuclear scientists and engineers in the free world for the next 20 years. It established an industry with strong educational underpinnings and established a market for nuclear energy. It also diverted adversary resources to peaceful nuclear applications and laid the foundation for the (NPT). For example, the USSR responded to Atoms for Peace by initiating an analogous program in the Eastern Bloc called the Community for Mutual Economic Assistance (CEMA). This collaborative and US-led research into the beneficial uses of nuclear technology for nonproliferation goals is as important today as it was in the 1950s.

As a result of recent bilateral discussions concerning the possible disposition of excess defense materials, substantial information has become available regarding the worldwide inventory of weapon-usable materials. Throughout the world, the total HEU and plutonium stockpile is now approaching 3,000 metric tons – enough fuel to supply US reactors for 20 years - <u>or</u> enough material for hundreds of thousands of crude nuclear devices if it were sufficiently pure chemically and isotopically.

From a materials perspective, one goal is to reduce and/or assure controls over the use of foreign-origin HEU, uranium-233, plutonium, and other weapon-usable materials. This mission supports a policy that reduces the quantity of foreign fissile materials that could be diverted to weapons uses. As part of this policy, the Department encourages the conversion of foreign research reactors from the use of HEU fuel to the use of LEU fuel. To support that policy, the Department accepts spent nuclear fuel from foreign research reactor for stabilization and disposal. The Department has developed technologies such as the melting and diluting of aluminum-based fuels and immobilization of nuclear materials to meet the spent fuel standard. The Department also provides monitored storage of foreign research reactor spent nuclear fuels and foreign-origin, weapons-usable materials until a national geologic repository is available for disposal of these materials.

The quantity of foreign-origin nuclear materials received by the Department in the future will be a function of the success of the Department's nonproliferation mission. This includes DOE's success in convincing foreign governments and organization to convert research reactors to low enriched uranium fuels prior to 2025, as well as the number of foreign governments and organizations that have taken advantage of the Department's offer to store and dispose of these spent nuclear fuels and other weapon usable materials.

With the above in mind, the range of mission scope within the nonproliferation area contains uncertainty and is broad. If the bilateral agreements between the US and Russia become treaty provisions, increased warming of relations will likely underwrite the future profile. Cooperative development and deployment of monitoring technology will increase. Increased international inspections and joint research will result. A visible transition toward a peaceful nuclear future will occur.

If, on the other hand, the bilateral agreements are not achieved, there will likely be a continued effort toward information gathering in an effort to curtail the movement of nuclear materials and weapon technology around the globe. Less cooperation will occur and less international involvement will exist. The overall size of the nonproliferation program will remain the same, although the emphasis will change dramatically.

6.2.4 Energy

Collaborative R&D activities have formed the basis of US proliferation prevention policy since the beginning of the Atoms for Peace initiative. The Department's energy mission [12] includes the promotion of the safe, secure, and legitimate use (as defined by the NPT) of nuclear energy by supporting the development of the next generation nuclear reactors and fuel cycle. Some of the activities it supports include development of enrichment technology, fuel/target fabrication, high-risk research and development, and research on the back-end of the fuel cycle (nuclear material recycle, partition-transmutation, and disposal). The Department also supports the production of isotopes for medical, industrial, and civilian space needs. The future mission space for DOE in this arena will depend on the extent to which it continues to support these activities. Privatization is under consideration. Thus the future mission of DOE in nuclear energy would range from a very low level of support to a vigorous leadership role in technology development for commercial nuclear power production and for isotope production.

To maintain its options in this area, DOE would need to maintain sufficient fissile materials to enable development of the next fuel cycle and to maintain reserves of feedstock materials that are not available in the private sector and that are essential precursors for isotope production. An example of such a feedstock material is neptunium-237, which is irradiated to produce plutonium-238. Plutonium-238 is the heat source for radioisotope thermoelectric generators that are used as power sources for NASA's deep space missions.

6.2.5 Environment

The environmental mission of DOE is to remediate and restore sites that have become contaminated over the past 50 years of weapons production [15]. This work includes the treatment, storage, and disposal of radioactive and hazardous legacy wastes from the DOE nuclear weapons complex. It also includes handling wastes generated during the decontamination and decommissioning of facilities, and the environmental restoration wastes generated during the cleanup of the DOE sites. In addition, the environmental mission is also responsible for the management of DOE-owned spent nuclear fuel. This includes stabilization, transportation, storage, and disposal. DOE accomplishes this mission through chemical separations, stabilization, and immobilization of materials; the storage of these wastes and products; disposal of waste products; and the recovery and reuse of certain materials. DOE has an active program to minimize waste production during its operations.

The quantity of waste that DOE must manage by the year 2025 will partially depend on how well it has accomplished its mission prior to that time. By 2025, some DOE sites will have reached closure and much of the radioactive and hazardous materials at those sites will have been disposed of. Even though environmental management activities would remain at the other sites, much of the waste material at those sites also will have been treated and disposed. It is expected that the treatment of HLW in tanks at the Hanford Site would be not completed by 2025 nor will the treatment of HLW at the Idaho National Engineering and Environmental Laboratory (INEEL).

The scope of the environmental mission is not deemed to be sensitive to the scope of other nuclear materials missions. Rather, it is dependent on the rate at which the nation chooses to remediate its legacy facilities and waste.

6.2.6 Science

An important dimension of the DOE science mission is to preserve and supply nuclear materials for future scientific, defense, medical research and development needs, and fundamental scientific studies [13]. Many different nuclear materials are required for these activities. The feed-stocks required to produce certain isotopes were obtained during separations activities that are no longer conducted by the Department. An example of such a feedstock material is neptunium-237, which is irradiated to produce plutonium-238. Plutonium-238 is the heat source for radioisotope thermoelectric generators that are used as power sources for NASA's deep space missions.

Furthermore, there are no other domestic sources for these materials. Indeed, the Department is the custodian for a significant variety and quantity of nuclear material defined as "national asset" material because it cannot be readily replaced. Some of this material does not have a current mission assignment but storage and management will be required in the future.

The future mission space for these science activities is either for DOE to continue to provide support or for DOE to cease its involvement in nondefense nuclear matters, discontinue support, and to rely on the private or international sectors for supply.

6.2.7 Naval Reactors

The Office of Naval Reactors is responsible for the development of nuclear propulsion systems for the U. S. Navy. Its mission also includes maintaining an assurance of an adequate supply of HEU for naval reactor fuels, fuel fabrication, and maintaining testing capabilities related to fuels and materials.

To support this mission, Naval Reactors maintains a nuclear reactor to test the effects of irradiation on materials. Although it does not store extensive quantities of HEU for future use in its reactors, it has laid claim to most of the HEU declared to be in excess of nuclear weapon needs. It is anticipated that Naval Reactors would also claim any additional HEU that becomes available through further reductions in nuclear weapons requirements.

In addition, Naval Reactors is responsible for the storage and disposition of naval spent nuclear fuel. Currently, spent fuel is stored at Idaho with disposition planned for the commercial spent fuel and HLW repository.

The scope of Naval Reactors is not deemed to be sensitive to the scope of other nuclear materials missions. Rather, it is dependent on the fleet size and tempo of operations. Neither of these is within the jurisdiction of the DOE.

6.3 Interrelationships amongst DOE Missions

The DOE missions described above are interdependent with one another. During this transition phase (2000-2025), the Department's materials management function is faced with a number of conflicting mission drivers. Decisions made to support one mission may have a considerable impact on another mission. This is probably most clearly seen in the national defense arena where treaties limiting the number of nuclear weapons directly affect the quantity of nuclear materials available for conversion to MOX fuel or processing for disposal. This section describes selected interrelationships among the various missions as illustrations of their interdependence. Interrelationships discussed below include

- Nuclear weapons mission vs. arms control mission
- Arms control mission vs. nonproliferation mission
- Nuclear energy vs. nonproliferation
- Nulcear energy vs. environment
- Use of reactors or accelerators for multiple missions
- Legacy disposition path vs. arms control/nonproliferation

6.3.1 Nuclear weapons mission vs. arms control mission

The size of the nuclear weapons stockpile has a direct relationship to the quantities of nuclear materials available for disposition under arms control regimens. A larger nuclear weapons stockpile and nuclear weapon production rate would require construction of a large pit production facility. However, facilities for storage and processing of surplus nuclear materials could be more limited in capacity. As treaties limit the number of nuclear weapons that each country may possess, a new pit production facility could be smaller (perhaps associated with research and development facilities). Under this scenario, more nuclear material would become surplus to each country's national defense requirements. This would mean that facilities constructed to convert plutonium to MOX fuel, vitrify surplus plutonium, blend down highly enriched uranium, and store these nuclear materials would need to operate longer or at higher capacities.

6.3.2 Arms control mission vs. nonproliferation mission

There are several examples of inconsistencies between the arms control and nonproliferation mission areas. The MOX option is likely the best way to consume nuclear weapon materials, yet it seems inconsistent with US policy regarding civilian MOX cycles. In PDD-13, the President stated the policy, "The US does not encourage the civil use of plutonium, and, therefore, does not itself engage in reprocessing plutonium for nuclear weapons or nuclear power." Thus, the policy was clearly about reprocessing and not about consuming the plutonium that is already separated from prior defense-related reprocessing.

There is a move to close all remaining defense reprocessing capabilities in the US as a nonproliferation example. Yet, two unexpected proliferation concerns arise: (1) thousands of Russian nuclear weapons could be "traded" (diverted into MOX cycle) in exchange for materials that could be "cleaned" by aqueous processing, and (2) some highly enriched US material forms that are "orphaned" have no disposition path except direct disposal in a repository designed for commercial, light water reactor spent fuel. Mortgage reduction drivers for US legacy materials also conflict with arms control and nonproliferation goals. Dilution and direct disposal become the preferred options, although these options are inconsistent with Russian trade materials.

If the US and other countries cannot come to agreement in the management of nuclear materials, the Department's nonproliferation mission would assume greater importance. The US would not be able to overtly monitor other countries' management of nuclear materials. Accordingly, the emphasis on nuclear materials monitoring would shift from overt monitoring systems, where each country monitors the other's facilities, to more covert systems, where monitoring would be done by satellites or other remote means.

6.3.3 Nuclear Energy R&D vs. Nonproliferation

As was demonstrated by Atoms for Peace in the first nuclear era, and will likely be demonstrated in future former Soviet Union (FSU) Western activities, open and transparent collaborative research in the beneficial uses of nuclear technology is the most cost-effective and successful deterrent to nuclear proliferation by partner countries. Yet, the "maturation" of the US domestic industry has caused a substantial lack of investment in US-led advanced fuel cycle research. For example, other countries are forming regional partnerships that do not include US participation, global industry partnerships are forming outside the US, and the US ability to influence through US-origin materials is decreasing year to year.

6.3.4 Nuclear Energy vs. Environment

A primary environmental concern regards the safe disposal of radioactive waste. If disposal of spent fuel is not satisfactorily resolved, the potential harm to the environment and future generations may be significant. The implication, therefore, is that nuclear energy is bad for the environment.

However, as concerns of greenhouse gas emissions increase, the level of carbon emissions become an important consideration in the evaluation of energy production and conservation. The Kyoto Accords commit the US to significant reductions in the amount of carbon that it can release into the atmosphere. If fact, the reduced levels are so great that the only practical way to achieve the goals in the stated time frame is to increase the proportion of nuclear to carbon-based power produced. This issue re-opens the role of nuclear energy in the US

6.3.5 Use of reactors or accelerators for multiple missions

By 2025, many of the Department's irradiation sources will have reached the end of their useful lives. Furthermore, changes in the DOE mission may lead to a reduction in the need for irradiation. For example, DOE could decide to privatize certain functions such as the production of industrial and medical isotopes. The Department has an opportunity, especially if it assumes a smaller responsibility, to use its reactor(s) and accelerator(s) for multiple programs rather than construct separate irradiation sources for each. If the SBSS program continues, the Office of Defense Programs will require a reactor or accelerator for the production of special isotopes necessary for stockpile certification. Integration of other mission requirements could make these functions more efficient.

6.3.6 Legacy disposition path vs. arms control/nonproliferation

There is an opportunity to use the Savannah River Site (SRS) canyons to process surplus residual plutonium that is considered separable into weapons-grade plutonium. Using the canyons, the residual plutonium could be processed into weapons-grade plutonium to increase the US inventory for negotiation purposes with the Russians. Since the Russians have substantially more weapons-grade plutonium than does the US, this option increases the US ability to negotiate further reduction of the Russian stockpile.

This is an alternative path to the current plan to dispose of surplus plutonium at the Waste Isolation Pilot Plant (WIPP). The trade-off is permanent disposal of all US surplus plutonium vs. the leverage of using this plutonium as a means to further reduce the Russian stockpile.

7.0 Materials Analysis

The proper management and control of nuclear materials in the US and abroad is an important national security objective that requires DOE leadership. Regardless of the future of nuclear weapons or nuclear energy, DOE will be responsible for a vast array of nuclear materials for generations to come.

Based on the seven defined missions, specific fissile materials, nuclear components, and nuclear wastes that will need to be managed in the complex include the following:

- Nuclear Weapons: To maintain a safe and secure nuclear weapons stockpile, the need for plutonium and uranium will continue. While there are sufficient stockpiles of both materials, plutonium will need to be constantly processed and recycled. There may be a need to also produce uranium in the timeframe shortly after 2025. This eventuality will require planning for production of HEU to begin within the 2025 timeframe. In addition, tritium will need to be produced. Ongoing treaty negotiations, such as the START treaties, may limit the scope of work required for each material, but the fact remains that plutonium, uranium, and tritium will be needed to maintain the nuclear deterrent. Lithium is also needed for nuclear weapons although there is sufficient lithium in the stockpile and reserves. However, this material requires storage and will eventually be introduced into the weapon stockpile. In addition, certain special isotopes will be needed to support the SBSS program. This is required as an aspect of the transition from nuclear testing at Nevada to small-scale, sub-nuclear testing in experimental facilities. Production of special isotopes will require fuel synthesis, irradiation, and separation/purification.

- Arms Control: The focus of the arms control mission area is to eliminate surplus plutonium and highly enriched uranium. The storage and eventual disposition of plutonium and uranium is key in this mission area. The material form currently consists of oxides, fuel, and weapons components. Other forms, such as residues and metals may eventually be included in future arms control agreements. Depending on arms control agreements, plutonium could be used in MOX fuel assemblies and burned in commercial reactors, or placed in cans that are then suspended in vitrified high-level waste glass logs for disposal.

- Nonproliferation: Fissile materials associated with nonproliferation are essentially the same as for the arms control mission area with the exception of cesium and strontium. These two fission products result from the separation process and must be properly stored and disposed.

- Energy: Energy identifies the need to maintain a capability to develop isotopes for advanced fuel cycles, plutonium-238 as heat sources for deep space probes, and medical uses. In addition, the stewardship over existing special materials, which includes packaging, storage, safeguards, and distribution, must be maintained.

  The Report to the President on Federal Energy Research and Development for the Challenges of the Twenty-First Century [5] has recommended significantly expanded research to address economics, advanced materials, safety, and world leadership issues associated with the safe and efficient use of nuclear energy.

The main waste product that will be generated by the Energy mission area is spent fuel from advanced fuel cycle and reactor development.

- Environment: The main materials responsibility for the environment mission area is the effective disposition of fissile materials and nuclear waste generated in the DOE over the last 50 years [15]. This legacy waste includes transuranics (TRU), HLW, spent fuel, and LLW. This responsibility encompasses safe and& secure storage, transportation, and disposal of fissile materials from the weapons program and nuclear waste generated during the cleanup of sites.
- Science: The science mission area requires the capability to develop special research and medical isotopes to support fundamental science [13]. In addition, the stewardship over existing special materials, which includes packaging, storage, safeguards, and distribution, must be maintained.
- Naval Reactors: Naval Reactors require highly enriched uranium and nuclear fuel to support naval propulsion systems. In addition, the DOE is also responsible for the storage and disposal of navy spent nuclear fuel.

8.0 Functions Analysis

8.1 Overview

To evaluate the integrated mission needs for the post-2025 future of the Department, a common set of scientific functions were identified as capabilities that will be required to meet the 2025 needs of the seven mission areas. These functions were then evaluated against each mission area and used in assessing the extent to which functions and facilities are needed for securing the individual mission success for each office within the Department. Once the functional analysis was completed against each office mission, a summation across all offices was performed. High and low cases were defined and used in assessing the scale of each function within each office mission. The result of that summation then indicates the bounding configurations in terms of the types and scale of each function within the 2025 complex. A sensitivity analysis to assess how the sensitivity of changes in the assumptions and missions to the various functional needs within the Department was then performed.

This analysis identifies needed functional capability. It does not address, or mean to imply, any capacity requirements for the functions. The qualitative nature of the analysis cannot support any quantitative assessments of needed capacity for the individual functional requirements at this time. The scale for each function is identified as small, medium, or large. This scale is a qualitative assessment of the level of capability that will be required to meet the stated goals of the mission.

8.2 Functions Definitions

The various functions selected represent a generic flow of nuclear materials through the processing sequence for each of the mission areas.

1. Fabrication: Fabrication is any set of processes used to transform raw materials to usable components or to take usable components apart and to turn them back into raw materials. Included are such processes as metal fabrication for weapon components and ceramic

fabrication for fuel components. Also included is the disassembly of weapon components and converting the nuclear materials into raw materials suitable for disposition or refabrication.

2. Irradiation: Irradiation includes any process to convert materials into usable isotopes for programmatic use. Irradiation may be by nuclear reactors or accelerators, depending on the specific application. Examples of irradiation processes include the production of medical isotopes, heat source isotopes for fueling deep space probes, special research isotopes, and special defense isotopes. Generally, this mission is viewed as being of relatively small scale.

3. Separations/Enrichment: Separations include the technologies needed to receive irradiated fuel, target, and blanket materials and to extract the usable nuclear materials from the irradiated materials. The technology requires use of remote handling facilities such as separation canyons or hot cells where remote or semiremote handling can be accommodated. Generally, this technology is defined to represent the separation of usable isotopes from radioactive waste byproducts. Enrichment is the process used to concentrate the separated usable isotopes.

4. Storage: Storage includes the technology necessary to package, certify, transport, and store nuclear materials for meeting both continuing mission and end-of-mission requirements. Included in these technologies are above-ground storage facilities utilized in supporting continuing defense and energy missions and interim storage necessary to stage materials pending disposition and disposal.

5. Processing: Processing involves any chemical and metallurgical treatment of materials where recycle and purification is necessary for achieving mission requirements. Included is recycle of fabrication residues, down-blending for meeting isotopic requirements, purification for meeting product specification, and waste treatment necessary for meeting regulatory requirements.

6. Monitoring: Monitoring involves the development, testing, fabrication, and deployment of sensors, monitors, detectors, and communication systems necessary to track the movement and location of nuclear materials both from an individual facility safeguards standpoint and from the more global nonproliferation standpoint. It includes the use of physical, chemical, and radiological systems as well as the data acquisition and communication systems necessary to support the sensors.

7. Disposal: Nuclear materials are disposed of in three generic forms: HLW, including spent nuclear fuel; TRU; and LLW. TRU and LLW waste materials may also contain hazardous components as defined by the Resource Conservation and Recovery Act (RCRA) or the Toxic Substance Control Act (TSCA), which are regulated by the EPA. The facilities necessary to support transportation, disposal, and monitoring of disposal sites for each of the three categories of waste are included in this area.

8. Science-Based Stockpile Stewardship Research and Development Functions**:** Included here are the nuclear materials related research facilities/functions necessary for meeting the SBSS transition resulting from the CTBT. Included would be upgrades to current plutonium research facilities, criticality research, hydrodynamic measurements, and stockpile components and materials testing functions.

Table 2 shows the relationship of the Department mission areas with the various functions. Imbedded within the matrix are the various materials and/or activities needed to support the mission areas.

As can be seen from the figure, most functions have some impact on the success of each mission area. The actual impact can only be ascertained by evaluating the overall scope of each mission area. The actual impact will be a function of the scope of work in each mission but, as discussed earlier, each mission can have both a counteracting and an additive impact on a mission elsewhere in the Department. The range of activity within each mission area was discussed earlier. In evaluating the impact of functions on each area, these ranges are used to establish bounding scenarios.

Table 2**:** 2025 nuclear materials functions versus missions

Functions	Weapons	Arms Control	Nonproliferation	Energy	Environment	Science	Naval Reactors
Fabrication	U, Pu, T, Li, etc.	MOX, PDCF		Fuel, 238Pu		Isotopes	Fuel
Irradiation	Isotopes	MOX, U blend		Transmute Waste		Isotopes	
Separations	Isotopes		Cs/Sr	Isotopes		Isotopes	
Storage	Pu, U, Parts	Pu, U, Fuel, Parts		Isotopes	Waste	Isotopes	
Processing	Pu, U, Parts	PDCF, Immobil.		Fuel, 238Pu, Pu	Cleanup Materials	Isotopes	
Monitoring	Safeguards	IAEA	Treaties	Safeguards	Safeguards	Inventory	
Disposal	TRU, LLW, Mixed	TRU, LLW, HLW		Spent Fuel	TRU, LLW, HLW		LLW, HLW
SBSS	Isotopes & Certification						

9.0 Scenario Development

The missions were analyzed under different scenarios to define boundaries around the level of resources required to meet the mission requirements. In analyzing the seven mission areas, a rational discriminator for selecting scenarios revolves around the defense (i.e., weapons, arms control, nonproliferation, and naval propulsion) and non-defense (i.e., energy, environment, and science) missions. Therefore, the scenarios are selected by coupling the defense missions and the nondefense missions. This coupling is a result of the relatively stronger interrelationships within the defense and nondefense sectors, as opposed to across sectors.

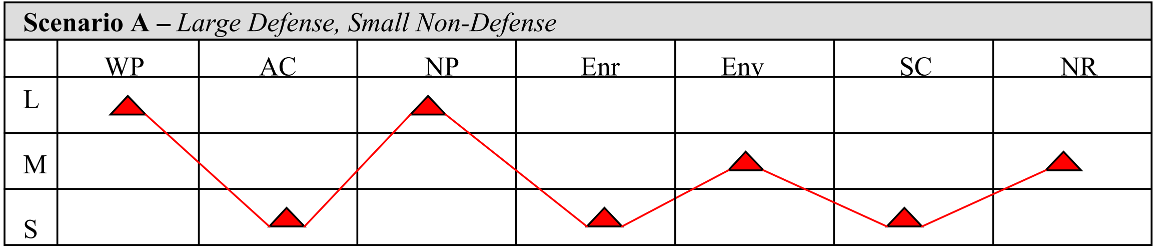
In order to properly evaluate mission requirements in this scenario analysis, mission needs are translated into functional needs by assigning functional requirements of “large” and “small” to the defense and nondefense sectors. These two functional parameters relate to four possible combinations, or scenarios. The four scenarios can be described as follows.

Scenario	Defense Scope	NonDefense Scope
A	Large	Small
B	Small	Large
C	Large	Large
D	Small	Small

In this analysis, the functional parameters "large" and "small" are necessarily qualitative in nature. This analysis is meant to provide an indication of level of capacity that will be needed to achieve the 2025 Vision, not specific facility capacities. Figure 3, below, provides more specific definitions for "large" and "small." In addition to this qualitative assessment of size, each scenario was evaluated for internal consistency between the mission areas to ensure that all dimensions of nuclear materials management were properly addressed.

A detailed discussion of each of the four scenarios follows.

Scenario A: Large Defense Scope and Small Nondefense Scope



9.1.1 Weapons: The stockpile size is similar to the stockpile mandated by START I, for the purposes of defining the needs for exchanging limited-life components like tritium reservoirs. The allowable time that a weapon can remain deployed before concerns arise over its continued viability and safety is found to be short, thus requiring fabrication of up to 500 pits per year. Modern production facilities are built to support this scope and are separate from the SBSS facilities. There is a continuous production of special isotopes for SBSS purposes from irradiation with the concomitant separation function. Storage requirements are sized to support fabrication and stockpile reserves. In addition, Defense Programs provides storage for Naval Reactors Programs for the long term. Chemical processing and recycle, waste management, and monitoring are sized to support the fabrication functions. The full suite of SBSS special facilities is functional for support of the stockpile in the absence of NTS.

9.1.2 Arms Control: The scope of the nuclear materials removed from weapons uses because of arms control agreements does not exceed that stated today: 38.2 metric tons of weapons-grade plutonium and 174 metric tons of HEU. Bilateral agreements on disposition are in place but the mission is not complete. MOX fabrication and Pit Disassembly and Conversion Facility (PDCF) processing are obvious features that drive a modest chemical processing and waste management function. International inspections are the main feature for the monitoring function.

9.1.3 Nonproliferation: Cooperative international and domestic monitoring is the cornerstone of the nonproliferation scope. Instrumentation is being developed and deployed for meeting both treaty agreements and intelligence gathering. This is an active program in support of nuclear material tracking and management.

9.1.4 Energy: The Department has disengaged from nuclear energy issues and has left the issues of nuclear power to the domestic and international commercial sectors. All medical and scientific isotopes are purchased from the commercial sector. The only remaining scope of work addresses storage of residual inventories of feeds, separated isotopes, and the monitoring and disposal of residual materials.

This scenario is also consistent with the US policy of not reprocessing. It is important to note that_this policy affects both defense and nondefense mission areas within the DOE in terms of nonproliferation (defense) and development of a next-generation fuel cycle (nondefense).

It is also important to note the international implications of this policy. While the US policy is to not reprocess, other nuclear nations do reprocess spent fuel as a national policy to ensure energy independence. While these countries policies are derived from an energy perspective, it places added responsibility on the US to deal with the proliferation concerns implicit to reprocessing. It is important to recognize the inescapable international role that the US has in maximizing the nonproliferation of fissile materials with regard to the reprocessing of spent fuel in other nuclear nations. This highlights the Imperative of Engagement for the US, regardless of the level of engagement that is eventually chosen.

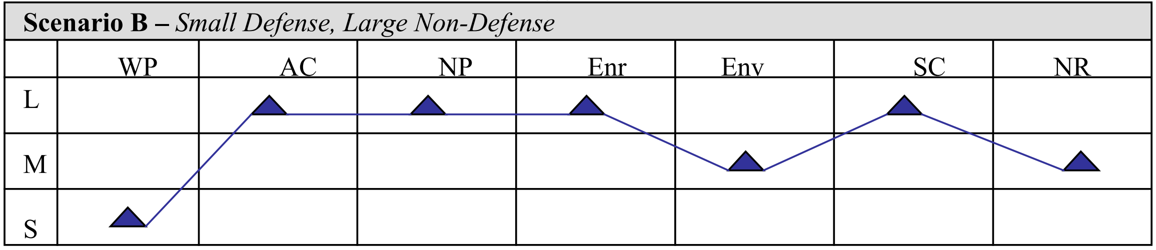
9.1.5 Environment: The scope of the environmental program continues to involve residual work remaining from the cleanup of cold war sites and facilities, and the interim management of materials and debris pending disposal. The primary continuing function is the programmatic operation of the waste disposal sites for LLW, TRU, and HLW.

9.1.6 Science: The Department has disengaged from nuclear energy issues and has left the issues of nuclear power to the domestic and international commercial sectors. All medical and scientific isotopes are purchased from the commercial sector. The only remaining scope of work has to do with storage of residual inventories of feeds, separated isotopes, and spent fuels and the monitoring and disposal of residual materials.

9.1.7 Naval Reactors: The scope of work in Naval Reactors is strictly dependent on the fleet size and tempo of operations. Neither of these is under the jurisdiction of the DOE. Nuclear work consists of materials-of-construction/material-lifetime studies and fuel certification activities. In addition, nNaval Reactors must store, transport, and dispose of spent fuel.

This scenario is internally consistent in that under a large weapons scenario, significant quantities of nuclear materials are tied up in the production functions and, therefore, the arms control scope of work is constrained to smaller quantities. The Nonproliferation mission has an emphasis on intelligence with some cooperative equipment deployment. Foreign research reactor fuel is being received and disposed of in the United States. The nuclear material scope for the Nonproliferation program can be met by the defense facilities. Special isotopes for SBSS scope will need to be produced by the defense sector but can be self-contained, as an irradiation source can be custom designed to provide those materials in the most cost-effective fashion. The nondefense scope can be totally market driven and provided from the private sector. The only inconsistency appears to be the fact that an irradiation source will need to be built to support SBSS and could be used to supply special medical and science isotopes if designed to do so. Integration of missions between defense and nondefense would be necessary for this dimension of scope to be feasible. The only inconsistency may be the nation's ability to utilize nuclear power to address international agreements concerning greenhouse gas emissions. Without an institutionalized nuclear power development program, the nation will be totally dependent on the commercial sector for nuclear power development.

9.2 Scenario B: Small Defense Scope and Large Nondefense Scope



Scenario B – *Small Defense, Large Non-Defense*

	WP	AC	NP	Enr	Env	SC	NR
L		▲	▲	▲		▲	
M					▲		▲
S	▲						

9.2.1 Weapons: Under this scenario, SBSS has provided full confidence that deployed weapons will remain viable and safe for extended periods, and weapon rebuild or replacement rates are small. In addition, further START treaties have been reached, resulting in the need for a smaller infrastructure to support stockpile maintenance. The scope of weapon fabrication is about 20 pits per year for surveillance replacements and a small rebuild capacity. Because of the small rates, it is also possible to combine the research and the production functions into a single footprint as opposed to two separate building/site functions. There is a continuous production of special isotopes for SBSS purposes from irradiation with the concomitant separation functions. Storage requirements are sized to support a smaller fabrication requirement and a small stockpile reserve need. In addition, Defense Programs provides the storage capacity to support the Naval Reactors Programs for the long term. Chemical processing, recycle, waste management, and monitoring functions are sized to meet the smaller fabrication function. The full suite of SBSS special facilities is functional for support of stockpile surety in the absence of testing capability at the NTS.

9.2.2 Arms Control: Bilateral agreements with Russia have been successful. The lower scope of work in the weapons programs results in an increased scope of work in the disposition area. The PDCF and the Mixed Oxide Fuel Facility are either larger in footprint or the period of operation is extended to coincide with the quantities of materials declared excess to weapons use. International inspections are a main feature for the monitoring function.

9.2.3 Nonproliferation: International and domestic monitoring is the cornerstone of the nonproliferation scope. Instrumentation is being developed and deployed for meeting both treaty agreements and intelligence gathering. Although of different scope, this function is large.

9.2.4 Energy: The Department has re-engaged in nuclear energy from energy production, advanced fuels R&D, fuel cycle R&D, and advanced reactor design R&D. Partnerships exist with the public sector. Nuclear energy is viewed as one dimension toward addressing international agreements on the topic of greenhouse gas emissions.

Collaborations exist with other countries concerning space power. NASA continues with its deep space probe missions, requiring plutonium-238 fuel. Either Department or domestic reactors/accelerators produce all medical and scientific isotopes. Separation capabilities are sized to support these missions.

9.2.5 Environment: The scope of the environmental program continues to involve residual work remaining from the cleanup of Cold War sites and facilities, and the interim management of materials and debris pending disposal. The primary continuing function is the programmatic operation of the waste disposal sites for LLW, TRU, and HLW.

9.2.6 Science: The Department continues to provide the entire spectrum of isotopes for nuclear medicine and nuclear research. In addition, the Department hosts a wide variety of radiation research. This requires that a basic reactor and/or accelerator capability exists and that separation capability in the form of hot cells and high-exposure separations exists. Finally, the necessary monitoring, packaging, transportation, storage, and waste management functions are sized to support this research scope.

9.2.7 Naval Reactors: The scope of work in Naval Reactors is strictly dependent on the fleet size and tempo of operations. Neither of these is under the jurisdiction of the DOE. Nuclear work consists of materials-of-construction/material-lifetime studies and fuel certification activities. In addition, Naval Reactors must store, transport, and dispose of spent fuel.

This scenario is internally consistent in that under a small-weapons scenario, smaller quantities of nuclear materials are tied up in the production functions and, therefore, the arms control scope of work is maximized. The nonproliferation scope expands to include the receipt of significant quantities of foreign source nuclear materials, far beyond just the foreign research reactor fuels. Less emphasis is placed on intelligence functions with most involving material protection, control, and accountability (MPC&A) type functions around the globe. The nuclear material scope for the nonproliferation program can be met, for the most part, by nondefense facilities and to a much lessor extent by the defense facilities. Special isotopes for SBSS scope will need to be produced by the defense sector but can be self-contained, as an irradiation source can be custom designed to provide those materials in the most cost-effective fashion. The nondefense scope is revitalized and providing leadership, internationally. There is advanced reactor and advanced fuel research as an initiative to address the international agreements on greenhouse gas emissions. Medical and research isotopes are being produced and distributed for science and medical purposes.

9.3 Scenario C: Large Defense Scope and Large Nondefense Scope

Scenario C – *Large Defense, Large Non-Defense*							
	WP	AC	NP	Enr	Env	SC	NR
L	●		●	●		●	
M					●		●
S		●					

9.3.1 Weapons: The stockpile size is similar to the stockpile mandated by START I, for the purpose of defining the needs for exchanging limited-life components like tritium reservoirs. The allowable time that a weapon can remain deployed before concerns arise over its continued viability and safety is found to be short, thus requiring fabrication of up to 500 pits per year. Modern production facilities are built to support this scope and are separate from the SBSS facilities. There is a continuous production of special isotopes for SBSS purposes from irradiation with the concomitant separations function. Storage requirements are sized to support fabrication and stockpile reserves. In addition, Defense Programs provides storage for Naval Reactors Programs for the long term. Chemical processing and recycle, waste management, and monitoring are sized to support the fabrication functions. The full suite of SBSS special facilities is functional for support of the stockpile in the absence of NTS.

9.3.2 Arms Control: The scope of the nuclear materials removed from weapons uses does not exceed that stated today; 38.2 metric tons of weapons-grade plutonium and 174 metric tons of HEU. Bilateral agreements on disposition are in place but the mission is not complete. MOX Fabrication and PDCF processing are obvious features that drive a modest chemical processing and waste management function. International inspections are the main feature for the monitoring function.

9.3.3 Nonproliferation: Cooperative international and domestic monitoring is the cornerstone of the nonproliferation scope. Instrumentation is being developed and deployed for meeting both treaty agreements and intelligence gathering. This is a very active program in support of nuclear material tracking and management.

9.3.4 Energy: The Department has re-engaged in Nuclear Energy from energy production, advanced fuels R&D, fuel cycle R&D, and advanced reactor design R&D. Partnerships exist with the public sector. Nuclear energy is viewed as one dimension toward addressing international agreements on the topic of greenhouse gas emissions. Collaborations exist with other countries concerning space power. NASA continues with its deep space probe missions, requiring plutonium-238 fuel. Either Department or domestic reactors/accelerators produce all medical and scientific isotopes. Separation capabilities are sized to support these missions.

9.3.5 Environment: The scope of the environmental program continues to involve residual work remaining from the cleanup of Cold War sites and facilities, and the interim management of materials and debris pending disposal. The primary continuing function is the programmatic operation of the waste disposal sites for LLW, TRU, and HLW.

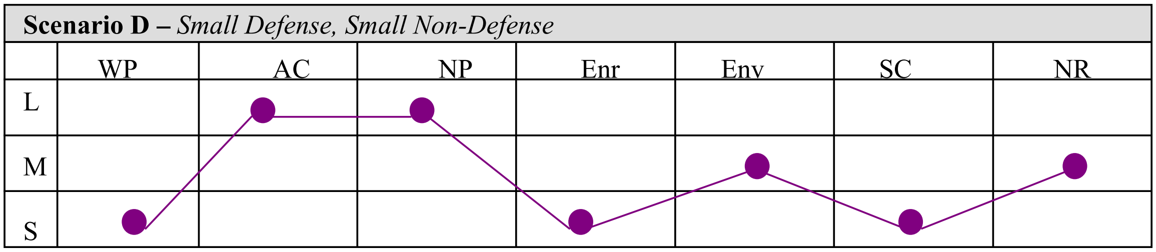
9.3.6 Science: The Department continues to provide the entire spectrum of isotopes for nuclear medicine and nuclear research. In addition, the Department hosts a wide variety of radiation research. This research requires that a basic reactor and/or accelerator capability exists and that separation capability in the form of hot cells and high exposure separations exists. Finally, the necessary monitoring, packaging, transportation, storage, and waste management functions are sized to support this research scope.

9.3.7 Naval Reactors: The scope of work in Naval Reactors is strictly dependent on the fleet size and tempo of operations. Neither of these is under the jurisdiction of the DOE. Nuclear work consists of materials-of-construction/material-lifetime studies and fuel-certification activities. In addition, Naval Reactors must store, transport, and dispose of spent fuel.

This scenario is internally consistent in that under a large weapons scenario, significant quantities of nuclear materials are tied up in the production functions and, therefore, the arms control scope of work is constrained to smaller quantities. The nonproliferation mission has an emphasis on intelligence with some cooperative equipment deployment. Foreign research reactor fuel is being received and disposed of in the United States. The nuclear material scope for the nonproliferation program can be met by the defense facilities. Special isotopes for SBSS scope will need to be produced by the defense sector but can be self-contained, as an irradiation source can be custom designed to provide those materials in the most cost-effective fashion.

The nondefense scope is revitalized and providing leadership, internationally. There is advanced reactor and advanced fuel research as an initiative to address the international agreements on greenhouse gas emissions. Medical and research isotopes are being produced and distributed for science and medical purposes.

9.4 Scenario D: Small Defense Scope and Small Nondefense Scope



9.4.1 Weapons: Under this scenario, SBSS has provided full confidence that deployed weapons will remain viable and safe for extended periods, and weapons rebuild or replacement rates are small. In addition, further START treaties have been reached, thus resulting in the need for a smaller infrastructure to support stockpile maintenance. The scope of weapon fabrication is about 20 pits per year for surveillance replacements and a small rebuild capacity. Because of the small rates, it is also possible to combine the research and the production functions into a single footprint as opposed to two separate building/site functions. There is a continuous production of special isotopes for SBSS purposes from irradiation with the concomitant separation functions. Storage requirements are sized to support a smaller fabrication requirement and a small stockpile reserve need. In addition, Defense Programs provides the storage capacity to support

Naval Reactors Programs for the long term. Chemical processing, recycle, waste management, and monitoring functions are sized to meet the smaller fabrication function. The full suite of SBSS special facilities is functional for support of stockpile surety in the absence of NTS.

9.4.2 Arms Control: Bilateral agreements with Russia have been successful. The lower scope of work in the weapons programs results in an increased scope of work in the disposition area. The PDCF and the Mixed Oxide Fuel Facility are either larger in footprint or the period of operation is extended to coincide with the quantities of materials declared excess to weapons use. International inspections are a main feature for the monitoring function.

9.4.3 Nonproliferation: International and domestic monitoring is the cornerstone of the nonproliferation scope. Instrumentation is being developed and deployed for meeting both treaty agreements and intelligence gathering. Although of different scope, this function is large.

9.4.4 Energy: The Department has disengaged from nuclear energy issues and has left the issues of nuclear power to the public and international sectors. All medical and scientific isotopes are purchased from the commercial sector. The only remaining scope of work has to do with storage of residual inventories of feeds, separated isotopes, and the monitoring and disposal of residual materials.

This scenario is also consistent with the US policy of not reprocessing. It is important to note that this policy affects both defense and nondefense mission areas within the DOE in terms of nonproliferation (defense) and development of a next-generation fuel cycle (nondefense).

It is also important to note the international implications of this policy. While the US policy is to not reprocess, other nuclear nations do reprocess spent fuel as a national policy to ensure energy independence. While these countries policies are derived from an energy perspective, it places added responsibility on the US to deal with the proliferation concerns implicit to reprocessing. It is important to recognize the inescapable international role that the US has in maximizing the nonproliferation of fissile materials with regard to the reprocessing of spent fuel in other nuclear nations. This highlights the Imperative of Engagement for the US, regardless of the level of engagement that is eventually chosen.

9.4.5 Environment: The scope of the environmental program continues to involve residual work remaining from the cleanup of Cold War sites and facilities, and the interim management of materials and debris pending disposal. The primary continuing function is the programmatic operation of the waste disposal sites for LLW, TRU, and HLW.

9.4.6 Science: The Department has disengaged from nuclear energy issues and has left the issues of nuclear power up to the public and international sectors. All medical and scientific isotopes are purchased from the commercial sector. The only remaining scope of work has to do with storage of residual inventories of feeds, separated isotopes, and spent fuels and the monitoring and disposal of residual materials.

9.4.7 Naval Reactors: The scope of work in Naval Reactors is strictly dependent on the fleet size and tempo of operations. Neither of these is under the jurisdiction of the DOE.

> Nuclear work consists of materials-of-construction/material-lifetime studies and fuel certification activities. In addition, Naval Reactors must store, transport, and dispose of spent fuel.

This scenario is not internally consistent because of the unclear source of investment in research and fundamental science in support of the remaining missions. This scenario involves the small weapons stockpile with smaller quantities of nuclear materials required for the production functions and, therefore, the arms control scope of work is maximized. Special isotopes for SBSS scope will need to be produced by the defense sector but can be self-contained, as an irradiation source can be custom designed to provide those materials in the most cost-effective fashion. The nonproliferation scope expands to include the receipt of significant quantities of foreign source nuclear materials, far beyond just the foreign research reactor fuels. Less emphasis is placed on intelligence functions with most involving MPC&A-type functions around the globe. It is not clear how the nuclear material scope for the nonproliferation program can be met. In addition, facilities for the development and testing of nuclear material sensors, detectors, monitors, and communications systems will be needed. This has been traditionally done in both defense and nondefense facilities. Nuclear material standards need to be prepared, certified, and stored. It is not clear how this function is adequately covered. The nondefense scope can be totally market driven and provided from the private sector. Medical and science isotopes would be procured from the public sector, the availability of which will be based on supply and demand. There will be local shortages and/or time delays in acquiring certain treatments and samples. The only inconsistency appears to be the fact that an irradiation source will need to be built to support SBSS and could be used to supply special medical and science isotopes if designed to do so. Integration of missions between defense and nondefense would be necessary for this dimension of scope to be feasible. The only inconsistency may be the nation's ability to utilize nuclear power to address international agreements concerning greenhouse gas emissions. Without an institutionalized nuclear power development program, the nation will be totally dependent on the commercial sector for nuclear power.

Overall, it appears that the three of the four scenarios (i.e., A, B, and C) are achievable with small internal inconsistencies throughout. These inconsistencies result from policy decisions either within the Department or from Congress. The scope of work in each mission area for each of the scenarios attempts to take into account the various interrelationships for mission space. The next step is to evaluate the extent to which scientific and facility functions are needed in addressing the spectrum of mission needs for each scenario. The result will then define, at a high level, the types of investments the Department will need to make independent of the vagaries of individual missions.

9.5 Functional Analysis of Scenarios

The first primary assumption to be made when evaluating the functional needs is that the nation and the Department will indeed retain missions in each of the Weapons, Arms Control, Nonproliferation, Energy, Science, Environment, and Naval Reactors sectors. The range of those missions is as defined above in both the mission section and in the scenario development section. Sensitivity analyses are then performed to test this assumption and to determine the impact that elimination of a mission will make on the results. Some example sensitivities are performed later in this section.

The second primary assumption has to do with facility construction. By 2025, essentially all of the current DOE complex of buildings and facilities will be in excess of 70 years old. It is therefore assumed that all of these facilities have been shut down or are in the process of closure.

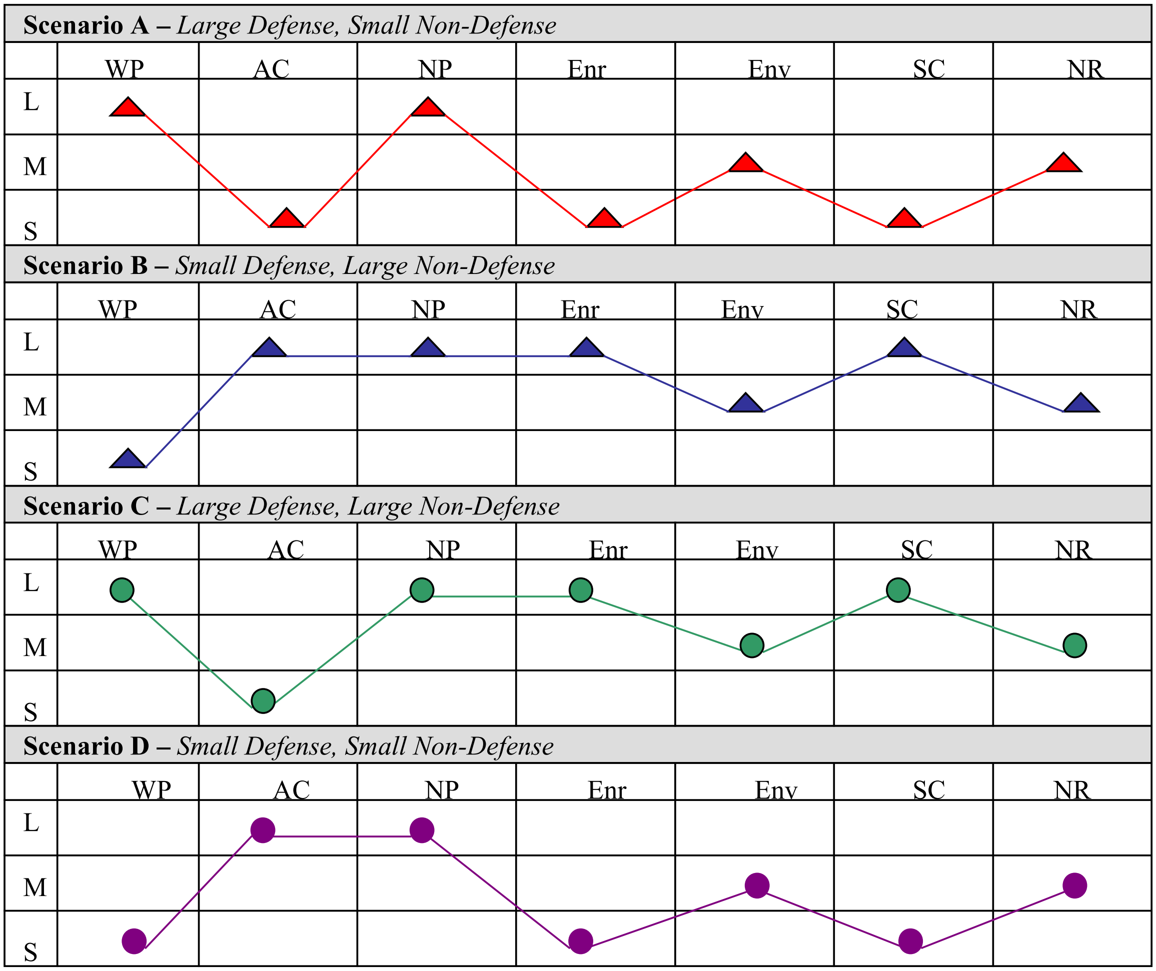
This means that the 2025 facility profile will be represented by modern and efficient new structures, all of which are less than 15 years old and many of which are essentially new. Because of this change, the DOE will have the opportunity to consider mission realignment amongst the various sites. It is expected that a number of sites will be closed and that the Department will choose to focus investment on a few sites only. No effort is made in this chapter to propose specific site/mission alignments.

Figure 3 represents a consolidation of the four scenario plots based on the discussions in the previous section. Stacking them together allows a pictorial view of the differences between the scenarios.

Using this information, it is now possible to translate the mission needs into functional needs. Table 3 represents this analysis of functional requirements on missions. Each function is rated for each mission area. The rating factors are large (L), medium (M), small (S), and zero (0). A rating of large indicates that the function will require a sizeable footprint and one that is likely a stand-alone facility. A rating of small indicates that the function will be needed to support that mission area but that it can very likely be integrated with other functions in a single footprint. A medium rating indicates that the function will be required but that its scope is such that it may or may not be able to be integrated with other functions. A zero rating indicates that the function has a zero scope of work relative to the scenario. Blanks in the figure indicate that the function is not applicable to the mission.

No analytic attempt was made to quantitatively sum the size of the facilities needed to assess each function, rather the judgment was subjective based on the relative sizes each requirement and the number of missions that needed each function. For example, the fabrication, storage, processing, monitoring, disposal, and science-based stockpile stewardship functions had at least one large functional requirement for each of the four scenarios. Neither the irradiation nor separation functions had a large functional requirement for any scenario; however, each had three small functional requirements for scenarios A and D and three small functional requirements and a medium requirement for scenarios B and C. If three missions had at least a small functional requirement, the overall evaluation was that the functional requirement was at least a medium requirement. Accordingly, the follow-up functional requirement for irradiation and separation was considered to be medium.

Figure 3. Consolidation of the four scenarios



Within the table the missions have been compared against the functional needs. The legend indicates how the scenarios have been noted within each cell of the table. Ratings have been determined qualitatively and an attempt has been made to consider the interrelationship of missions. The right-hand column of the table represents an overall assessment of the functional requirement for the future Department.

Overall, scenario A is nominally a small investment approach and scenario D is the minimum investment approach. Both acknowledge that the country continues to own nuclear materials and therefore retains an obligation to safeguard and dispose of the materials appropriately. The United States is a participant with others around the world in nuclear matters but has overtly determined not to be a driver of international policy in this arena. Under the scenario A, the scope of nuclear weapons fabrication is relatively large (up to 500 new units/year) indicating that most nuclear materials are tied up with this mission. Because of the scope of weapons fabrication, R&D and production are separated in footprint. This drives the arms control (disposition) scope to be smaller. Scenario D differs in that nuclear weapons fabrication is relatively small (20 units per year) and the scope of weapons R&D can be consolidated with production. The arms control scope must necessarily become larger. For both scenarios, the energy and science missions are driven to be small or nonexistent. Technology and special isotopes, such as for medical purposes, are procured.

Table 3: Analysis of functional requirements on missions

	WP	AC	NP	Enr	Env	SC	NR	Rollup
Fabrication	L S L S	S L S L		O S S O		S S		L
Irradiation	S S S S			S M M S	O O	S S	S S S S	M
Separation	S S S S	S O S O		S M M S	O S O S	S S		M
Storage	L L L L	S L S L	S S	S M M S	L M L M	S S S S	S S S S	L
Processing	L S L S	S L S L	S S	O M M O		S S		L
Monitoring	L L L L	L L L L	L	S M M S	M M M M			L
Disposal	M M M M	S L S L	S S	L L L L	L L L L	S S S S	S S S S	L
SBSS	L L L L							L

Scenario Legend:
A B
C D

L=Large
M=Medium
S=Small
O=Zero

commercially or internationally. The scope of nonproliferation is focused primarily on the identification and tracking of nuclear materials around the globe. The environmental mission continues to focus on facility/site cleanup without impact.

Scenario B is nominally a larger investment approach and scenario C represents the maximum investment approach. Both continue to acknowledge the variety of nuclear material management and utilization issues. The United States is more that just an international participant but rather exerts international leadership in the control and management of nuclear materials. In scenario B, the scope of nuclear weapons fabrication is relatively small (20 units/year) but the stockpile is supported out of modern and highly flexible facilities where R&D and production are collocated/integrated. Because of the small nature of the stockpile, more material requires disposition or storage (if retained for national security purposes), meaning that the arms control mission is maximized in the disassembly of weapon components and fabrication of MOX fuel. Scenario C arranges both nuclear weapons and arms control into the opposite configurations. The energy and science missions are significant and fully support transition to modern commercial nuclear power and the utilization of isotopes for medical and science purposes. Advanced irradiation and separations functions are required. Both the nonproliferation and environmental missions remain constant although the focus of the nonproliferation mission adjusts to support MPC&A and warming international relations.

9.6 Functional Roll-Up Assessment

A roll-up of the functional analysis is indicated in the right hand column of Table 3. The results are quite revealing. A comparison of functions indicates that although the scope of individual departmental office missions may vary, the functional needs for the nation remain relatively constant. The applications change based on applications within specific missions. It is important to note that these scenarios are chosen in an attempt to contrast the functional requirements within the Department, assuming certain missions.

Fabrication and Processing: The fabrication and processing functions are required to support both the nuclear weapon component fabrication and recycle, as well as the disassembly of components pending disposition (arms control) or continued storage for national security purposes. In addition, it supports the preparation and fabrication of fuel for MOX (arms control) and radioisotopic heat sources for NASA (energy). There are miscellaneous additional fabrications and processing needs but they are of a smaller scope. The pending bilateral agreements with Russia currently preclude the use of a single facility to perform all of these functions. The requirements for disposition include transparency provisions while the nuclear weapons mission retains high security. The agreement notes that the disposition facilities cannot be converted to defense purposes at the completion of the disposition task. This means that the Department must build at least two separate facilities, one for defense purposes and one for disposition purposes. Because of the scope of work within the disposition tasks will likely force the construction of at least two facilities; one for pit conversion and one for MOX fabrication. A subtle reexamination of the disposition tasks, together with the evaluation of needs for pit fabrication, could result in a consolidation of the pit disassembly and the pit fabrication tasks. Regardless of this outcome, the Department is faced with building a fairly significant fabrication capability, independent of the scenario selected.

Irradiation and Separation: The irradiation and separation functions are required to support the SBSS dimension of nuclear weapons, plutonium-238 production for NASA deep space exploration, naval reactor fuel and hardware certification, and medical and industrial isotope production. The medical and industrial isotope missions are the only ones at risk, depending on scenario. Given these other missions, an irradiation function must be provided as either a fission reactor or an accelerator. Without the capability to provide special isotopes, the various missions are unable to succeed. This means that a moderately sized irradiation source must be provided, independent of the scenario selected.

Storage: Storage is required to support essentially every mission, regardless of the range of operations. Table 3 indicates the extent of impact that a successful storage function has on success of the various missions. Because storage is so crosscutting, an opportunity exists to consolidate this function and provide it as a service to multiple mission areas. Regardless, the storage function must be large for the foreseeable future.

Monitoring: Monitoring is required to support essentially every mission, regardless of the range of operations. Table 3 indicates the extent of impact that the monitoring function has on the success of the various missions. Currently, the monitoring function is primarily consolidated into one DOE office but additional consolidation could achieve further efficiency. Independent of the configuration, a significant storage function is required, which will require monitoring.

Disposal: Disposal is required to support every mission area regardless of the scope of each mission area. Table 3 indicates this strong dependence. Currently an LLW repository is in operation at Nevada and a transuranic waste repository is in operation in New Mexico (WIPP). The Department has plans for the operation of a HLW repository, but this facility is at least a decade away from opening. The disposal function is essential to the future of nuclear materials regardless of the scenario. There are a number of waste streams, which cannot currently be disposed of as a result of regulatory and policy actions. Some wastes in this category include nondefense TRU waste, RCRA-mixed TRU waste, greater than class C waste, DOE spent fuel, and naval spent fuel. Overall, disposal repositories are an essential and critical element of the future nuclear materials management program of the country, independent of the selected scenario. The disposal capability needed, regardless of scenario, is large.

Science-Based Stockpile Stewardship: The transition away from the NTS for nuclear weapon stockpile certification introduced the need to expand the laboratory-scale development and testing of nuclear materials as the tool to certify the stockpile. This laboratory-scale testing includes the need for subcritical nuclear experiments and the need for various special isotopes to conduct various materials performance tests. The need for these facilities is articulated in the Defense Programs Plutonium Strategy. As the size of the stockpile shrinks, the importance of these facilities and materials increases as performance assurance becomes increasingly important. The need for this function is driven by the CTBT and is independent of the scenario selected.

10.0 Sensitivity Analysis

A critical component of this analysis is the evaluation of the sensitivity of the conclusions to variations in missions or barriers to program commitment. Five variants are selected as candidates for testing sensitivity. Table 4 displays the five variants together with the qualitative analysis of the sensitivity. Within the table is noted the variant and the forecast impact that this change will have on the mission space. Once the impact on mission space was determined, an evaluation was made on the impacts to the functions needed for overall DOE program success. The body of the table indicates the impact on missions and functions resulting from the variations. In all instances, the variants are tested against the integrated 2025 vision noted earlier. (This means that the variants are not taken as additive within this analysis.)

Variant 1: The bilateral agreements between the US and Russia are not reached.

The basic conclusion of this variant is that the arms control driver for disposition of excess materials no longer exists. The US will continue with aspects of the disposition program based on technical and scientific merits but the political drivers do not exist.

As noted in the table, it is assumed that having a secure START I stockpile increases in emphasis (weapons) while the various excess material disposition actions under arms control are all but stopped. There will be an increase in emphasis in nonproliferation monitoring of the movement of nuclear materials globally. There will be an increase in the needed storage capability, while there will be no measurable impact on the other mission sectors.

From a function standpoint, the, Fabrication, Irradiation, Separations, and Processing retain a DP focus although the scale of operations is within the anticipated range noted in the functions analysis earlier (20-500 units/year). Therefore, no increase in overall investment is anticipated beyond that already noted. There will be an increase in the Monitoring function in support of the nonproliferation mission. Finally, there will be an increase in emphasis on SBSS in terms of getting science-based tools in place and operational sooner.

Overall, this variant drives an increased emphasis in nonproliferation and SBSS activities.

Variant 2: Spent Nuclear Fuel Standard

The SNF standard, as described in the OCRWM Safeguards and Security Policy Guidelines [22], has three primary attributes: (1) fissile material content must be low enough to not be attractive to a proliferant (i.e., <5% by weight), (2) mass being sufficiently homogeneous to not have discrete concentrations of fissile material, and (3) the packages for storage and disposal are sufficiently large so as to be unattractive to theft.

The issue of concern is one of arms control and the current immobilization disposition path for excess plutonium. The "can-in-canister" concept may require significant additional security procedures to provide adequate safeguards and security protection. The programmatic impacts fall almost entirely on the disposition and environmental missions of the Department. There may be a general decrease in emphasis in the immobilization path as this is the path where relatively concentrated plutonium packages are placed in glass. If the glass waste form cannot meet the SNF standard, three alternatives are available: (1) the excess plutonium may be redirected into the MOX path for disposal, (2) the excess plutonium may be redirected to the disposal path for WIPP disposal, or (3) the immobilized glass waste form may require significant additional safeguards and security measures to assure proper management control of the plutonium.

If it is important to achieve maximum quantities of plutonium for reciprocity with Russia, the likely path will be MOX. These actions will create a delay in disposition and will therefore result in the need for increased quantities and time periods for storage and monitoring. From a functional standpoint, the primary impact is on the processing functions with some additional impact on the storage function. The magnitude of impact on the other functions is deemed to be of small significance. With regard to processing, materials currently destined for immobilization will require some separations and/or stabilization. This activity in not envisioned at this time.

Overall, the impact on DOE missions from a capability requirement standpoint is not deemed to be significant. The requirements for processing and storage will simply be traded against the requirement for immobilization.

Variant 3: Transmutation of Long-Lived Isotopes in Waste.

The issue with regard to transmutation is the potential to remove long-lived radioisotopes from spent fuel in order to demonstrate safe performance of the repository according to the NRC rules (10,000-year containment) [23]. Transmutation would allow for a more certain path to repository certification. The assumption is that if the DOE can remove the long-lived isotopes (actinides, technicium-99, and others), the safe performance of the repository can be credibly demonstrated in the 1000+ year time-frame. If the long lived isotopes are removed from the SNF prior to placement in the repository, the only remaining isotopes of concern decay in a relatively short time (i.e., < 1000 years). This result produces essentially a nonradioactive waste form after the short-lived isotopes have decayed. Transmutation of the actinides and others will require either an accelerator or a reactor. Because 100 percent efficiency on a once-through cycle cannot be achieved, a target recycle system will also need to be provided. Finally, the source of the feed for such a system is primarily spent nuclear fuel that contains long-lived isotopes. Extracting these isotopes will require the separations and processing of the spent fuel prior to target fabrication.

From a programmatic standpoint, the primary impacts land in energy, environment, and science. It is assumed that energy will host the actual transmutation system together with the target fabrication and fuel cycle processing. Together, energy and science will host the process R&D, target development, fuel cycle R&D, and transmutation system development and demonstration. Both of the program areas will experience significant increases in scope. Since the current program is focused on disposal within the environmental portfolio, this scope of work will decrease. Less material will be destined for disposal. The complexity of disposal will significantly decrease (shorter certification period) and the overall cost of disposal will decrease. The actinide materials currently destined for immobilization as part of the disposition program will go through transmutation or go through another path for disposal (e.g., WIPP).

Overall, implementing a transmutation function will result in a significant increase in scope for energy and science and a modest decrease in scope for environment in the near term. This will require significant up-front investment, the cost benefit of which will be realized in the far distant future as measured by cost savings in certification and operation of the HLW repository.

Variant 4: High-Level Waste Repository does not open.

The primary issue with this variant is the ability to obtain a license for the operation of the HLW repository. There are currently both political and scientific barriers to obtaining a license.

The programmatic implications of not having a national geologic repository are that materials will need to be stored in cooling basins, dry storage basins, vaults, etc. for long periods of time. The programmatic areas most affected by such an outcome include environment, nonproliferation and science. Without a disposal option, it is assumed that the immobilization path for excess weapons material will not move forward. Because environment is responsible for interim management of the current inventory of DOE spent fuel, this function will continue and plans for permanency will be required. Since the material will not be entombed in the repository, its attractiveness to diversion will remain, meaning that the emphasis on nonproliferation oversight will increase. Advancing the status of nuclear energy will be deemphasized, for without a waste disposal path, there will little desire for new-starts or for new reactor design. The role of science should increase in an effort to address the disposal problems and to find an alternate solution to the nuclear waste dilemma. The Navy Nuclear Reactors Program will also be significantly affected. If a repository does not open, the State of Idaho, through their agreement with the Department of the Navy and DOE, could stop all shipments of Navy fuel to the INEEL. The Navy could find itself in the position of either having to find an alternate storage location for their spent fuels or to cease decommissioning ships.

DOE's Energy missions will be further affected under this scenario. The NRC's waste confidence decision is a generic NRC proceeding to provide a justification, in every licensing procedure for reactors and spent fuel storage, to eliminate statutory environmental requirements to consider the availability of disposal in geologic repository. The NRC is presently committed to review the waste confidence decision every 10 years; the next review is scheduled for 2000. A major deferral in the repository program could adversely affect the waste confidence decision and lead to prohibitions against or limitations to reactor and storage decisions.

With regard to the functional areas, the primary impacts are in the areas of storage and monitoring. Disposal will be deemphasized. Above-ground storage will require the development of more advanced and enduring storage approaches with an integration of inspection and monitoring for addressing both the durability of materials question and the safeguards question.

Overall, this variant represents a continuing delay in reaching a final solution to the nuclear waste disposal challenge. Emphasis will increase for storage and monitoring at the expense of disposal. In the short term, there will likely not be an increase in overall expenditure. In the long run, the delay will result in increased expenditure because of the continuing interim management costs for these materials.

Variant 5: Use the Savannah River Site Canyons to reduce costs of the Material Disposition Facilities

There is a potential opportunity to use the SRS canyons to process excess residual plutonium that is considered separable into weapons-grade plutonium. Using the canyons, the residual plutonium could be processed into weapons-grade plutonium to increase the US inventory for negotiation purposes with the Russians. Since the Russians have substantially more weapons-grade plutonium than does the US, this option increases the US ability to negotiate further reductions of the Russian stockpile.

The viability of this scenario rests on the total amount of material that needs to be processed. As the total amount of material to be processed in the immobilization plant decreases, the viability of a standalone plant diminishes. At a certain point, keeping the canyons open and upgrading their capability provides a more efficient means to disposition of this material while providing the added advantage of increasing the US position to create a further reductions of the Russian plutonium stockpile.

This scenario assumes that the amount of material to be processed falls below the point of viability for the construction of an immobilization plant, and that the canyons will be used for disposition of the residual plutonium.

This scenario will not affect the nuclear weapons mission area. The amount of weapons produced is based on bilateral agreements that are extent of the excess plutonium in inventory. The arms control mission area will be affected by this variant. Producing weapons-grade plutonium will allow greater flexibility to negotiate further reductions of Russian plutonium. Increases in weapons-grade plutonium will result in an increase for nonproliferation mission activities. This variant will not affect the nondefense mission areas.

For functions, this variant will result in an increased need for MOX fuel fabrication. It is assumed that the added plutonium will be disposed of through incorporation into MOX fuel elements that will be burned in commercial reactors. The irradiation and separations functions are neutral to this variant. The storage function will increase due to an increase in weapons-grade plutonium.

For the processing function, the trade-off is between not building the immobilization plant/operating the canyons and building the immobilization plant/closing the canyons. This trade-off includes understanding the changes in waste generation for LLW, TRU, HLW, and Mixed Wastes. A trade-off study needs to be performed to quantify the net effect of this variant on the processing function. Qualitatively, the effect of this variant on processing appears to be neutral.

Monitoring of the added weapons-grade material will increase for the nonproliferation mission area. However, for the amount of material, the effect is incremental.

The effect of this material on disposal is neutral. Both waste forms are scheduled for disposal at the HLW repository. However, the MOX spent nuclear material will be easier to dispose of than the immobilized plutonium. At this point, there are no criteria established for allowing acceptance of the immobilized waste form into the HLW repository.

Table 4. Sensitivity analysis of selected variants

Missions	**2025 Rating**	**Variant 1: Bilateral Agreement Fails. Loss of MD**	**Variant 2: Spent Fuel Standard: Lack of Self-Protection**	**Variant 3: Transmutation of Waste**	**Variant 4: National Geologic Repository Cannot be Licensed**	**Variant 5: Use the SRS Canyons to Reduce the MD Costs and Increase Russian Trade**
Weapons		START I Firm, DOD wants more from DOE	None	None	None	None
Arms control		PIP, PDCF Unlikely, MOX:No	Increase MOX, Decrease PIP	PIP – eliminated	Decrease PIP, nul MOX	PIP-Eliminated Increase MOX
Nonproliferation		Increase	Increase storage monitoring	Increase	Increase	Increase monitoring
Energy		None	None	Increase R&D Transmutation, targets, fuel cycle	Decrease	None
Environment		None	Increase storage	Decrease	Increase	None
Science		None	None	Increase R&D, Transmutation, Fuel Development	Increase	None
Naval Nuclear Reactors		None	None	None	None	None
Functions						
Fabrication	L	DP focus: no significant effect	Increase MOX, Decrease PIP	Increase R&D target development, transmutation system, fuel development	None	Increase MOX Eliminate PIP
Irradiation	S/M	DP focus: no significant effect	None	Increase	None	None
Separation	M	No effect	None	Increase	None	None
Storage	L	None	Increase	None	Increase	Increase
Process	L	DP focus: no significant effect	Increase	None	None	Neutral
Monitoring	L	Increase	Increase	Increase	Increase	Increase
Disposal	L	None	None	Decrease	Decrease	Neutral
SBSS Lab R&D	L	Increase	None	None	None	None

11.0 2025 Complex for DOE

Given the results of this scenario and functional analysis, it is clear that the 2025 Vision for the nuclear materials complex will require investment in each of the mission and functional areas, regardless of the envisioned size of the complex. Table 5, below, illustrates the criteria used for each mission area in defining "large" and "small" investments. This table highlights the broad range associated with many of the parameters. In addition, many of the parameters are qualitative in nature. However, these qualitative factors still identify needs that will require a functional investment that must be factored into long-term planning.

It is acknowledged that numerous additional scenarios could be derived such as a situation where a large science program could be hosted with a small energy program. For simplicity sake, these defense and nondefense bases were selected at this time. Therefore, the four scenarios explore the relationship between large and small programs in each of these areas. More sophisticated scenario analyses will be performed later through the development and utilization of decision models within mission areas.

Table 4. Mission ranges, in terms of scope of work for mission area

Mission Areas	**Large**: Largest feasible mission without regard to other Department missions	**Small**: Smallest feasible mission without regard to other Department missions
Nuclear Weapons (WP)	➢ 500 Units per year ➢ START I size ➢ SBSS in place	➢ 20 Units per year ➢ START III ➢ SBSS in place
Arms Control (AC)	➢ >50 MT Pu excess ➢ Longer term of disposition ➢ Largest Storage required	➢ <50 MT Pu excess ➢ Short term of disposition ➢ Smaller Storage Required
Nonproliferation (NP)	➢ Large quantity of foreign fissile material to US	➢ Small quantity of foreign fissile material to US
Energy (ENR)	➢ Support nuclear reactor and fuel cycle development. ➢ Support industrial/medical isotope production ➢ Produce plutonium 238 for NASA space missions	➢ Eliminate nuclear reactor and fuel cycle development ➢ Cease industrial/medical isotope production. ➢ Purchase plutonium 238 for NASA space missions from Russia.
Environment (ENV)	➢ Dispose of more foreign fissile material.	➢ Dispose of less foreign fissile material
Science (SC)	➢ Active support of nuclear science	➢ Little or no support for nuclear science
Naval Reactors (NR)	➢ No impact	➢ No impact

As stated in a 1998 White House report, *A National Security Strategy for a New Century*, **"our strategic approach recognizes that we must lead abroad if we are to be secure at home, but we cannot lead abroad unless we are strong at home."[1]** The United States has to ensure safety and continue to improve the welfare of its citizen, while leading efforts to improve international stability. Safe and efficient management of nuclear materials is a critical component of this equation. A modern and efficient nuclear material complex can be the foundation to regaining US leadership in the nuclear arena and to continue pushing the scientific frontier.

With these principles, the 2025 DOE complex can be defined conceptually as requiring a significant capability for fabrication, storage, processing (recycling), monitoring and disposal, and a moderate capability for irradiation and separations. Sharing of capabilities will be possible, as long as it is done in accordance with applicable security requirements and international agreements. In fact, providing flexible, multipurpose facilities may be a requirement. For example, the chemical separations capability will be needed to produce defense isotopes (classified), treat some of the foreign nuclear materials resulted from nonproliferation initiatives (transparency), produce medical research isotopes (unclassified), prepare feed for transmutation if demonstrated to be feasible (unclassified), and support proliferation-resistant fuel cycle research (unclassified). Scientific knowledge and expertise developed to manage nuclear materials can be used for classified national security programs, transparent arms control and nonproliferation activities, and unclassified waste management and isotope production for scientific applications. Careful attention will have to be paid to ensure the availability of a sufficient continuing supply of talent at all levels to design, construct, operate, and maintain a safe and efficient nuclear materials management complex.

12.0 Acronyms

AC – Arms Control
CEMA – Community for Mutual Economic Assistance
CTBT – Comprehensive Test Ban Treaty
DOE – Department of Energy
DP – Office of Defense Programs
ENR – Energy
ENV – Environmental Management
EPA – Environmental Protection Agency
FSU – Former Soviet Union
GPRA – Government Performance and Results Act
HEU – Highly Enriched Uranium
HLW – High-Level Waste
IAEA – International Atomic Energy Agency
ICBM – Intercontinental Ballistic Missiles
L – Large
LEU – Low Enriched Uranium
LLW – Low Level Waste
M – Medium
MD – Office of Fissile Material Disposition
MIRV – Multiple Independently Targetable Re-entry Vehicles
MOX – Mixed Oxide
MPC&A – Material Protection, Control, and Accountability
MT – Metric Tons
NASA – National Aeronautics and Space Administration
NEPA – National Environmental Protection Act
NP – Nonproliferation
NPT – Nonproliferation Treaty
NR – Naval Reactors
NRC – Nuclear Regulatory Commission
NTS- Nevada Test Site
0 – Zero
OCRWM – Office of
PCAST – President's Committee of Advisors on Science and Technology
PDCF – Plutonium Disposition and Conversion Facility
PDD – Presidential Decision Directive
PIP – Plutonium Immobilization Plant
R&D – Research and Development
RCRA – Resource Conservation and Recovery Act
S – Small
SBSS – Science-based Stockpile Stewardship
SC – Science
SNF – Spent Nuclear Fuel
SRS – Savannah River Site
START – Strategic Arms Reduction Treaties
TVA – Tennessee Valley Authority
TRU – Transuranic Waste
TSCA – Toxic Substances Control Act
US – United States
USSR – United Soviet Socialist Republic
WIPP – Waste Isolation Pilot Plant
WP – Weapons

13.0 References

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